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Land Tenure Technologies
Summary of Services and Implementation

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Executive Summary

Land tenure refers to a set of land rights and land governance institutions, which can be informal (customary, traditional) or formal (legally recognized), that define relationships between people and land and natural resources (FAO, 2002). These land relationships may include, but are not limited to, rights to use land for cultivation and production, rights to control how land should be used including for cultivation, resource extraction, conservation, or construction, and rights to transfer – through sale, gift, or inheritance – those land use and control rights (FAO, 2002). Land tenure security – i.e., the level of confidence landholders have in their land rights – depends on the ability of informal and formal institutions to enforce those land rights and prevent others from challenging them (Feder & Feeny, 1991). In low and middle income countries, land tenure security has been linked to improved land management including greater investments to improve land and agricultural productivity (Deininger & Jun, 2006; Deininger, Ali, & Alemu, 2011; Ali, Deininger, & Goldstein, 2014; Lawry et al., 2017). Having legal documentation in particular has been associated with a greater sense of ownership over land, increases in land productivity and capital investments associated with land, and in some cases additional financial opportunities such as access to credit for landholders with formal land titles (Deininger, Ali, & Alemu, 2011). But in spite of the widely recognized benefits of land tenure security more than 70 percent of the world's population – and in particular many poor and vulnerable populations including ethnic minorities, smallholder farmers, and women – still lack access to formal systems to register their property and receive legally recognized land titles (Place, 2009; Enemark et al., 2014; Mitchell et al. 2016).

In this context many country governments and land rights organizations around the world are exploring ways to apply new technologies to improve land tenure security, either through identifying and formalizing customary land rights (e.g., by collecting data on indigenous land tenure arrangements), or through directly enrolling individual landholders in formal land tenure systems (e.g., through land registration programs providing individual landholders with legally binding land rights) (Lawry et al., 2017). The use of technologies can help disseminate information on land policies, simplify data collection on landholding boundaries and tenure status, facilitate land registration, titling, and record management, and has the potential to reduce the costs and time associated with delivering and administering land titles (Allen, 2014). Thus, when applied effectively, technology may make it easier for landholders to realize more secure land rights – and the associated benefits of more secure tenure – while also reducing the costs of government land administration systems.

This report begins with a brief overview of the extensive literature linking land tenure security to positive agricultural development outcomes in general, and among marginalized groups in particular, across a wide variety of contexts. We then draw on a review of recent literature to identify three main types of activities

that technologies may be used for in supporting land tenure security: **Type I - Support for Land Tenure Enabling Environment** activities include the application of technologies to provide access to information or legal guidance on land tenure rules, government policies, and regulatory frameworks; **Type II – Land Tenure Data Collection and Aggregation** activities include the use of technologies to collect, aggregate, and disseminate data about land and land tenure through maps and databases; and **Type III – Formal Land Titling** activities include the use of technologies to facilitate the land titling and transfer process for both landholders and governments. Through a review of online scholarly databases and systematic web searches we identified 38 land tenure technologies currently being applied to support land tenure security across the globe, and analyzed the characteristics of these technologies and their uses for land tenure security.

Most (27 out of 38) technologies engage in Type II (Data Collection and Aggregation) activities. Eight technologies are used to support Type I (Enabling) land tenure activities, and 16 support Type III (Titling) activities. All 38 technologies reviewed operate on a computer – desktop/application platform, and twenty-two can also be used on "smart" mobile devices and tablets. Three also provide services via mobile feature phones. All technologies require internet access for at least some part of their use, though many provide offline services such as land mapping tools that collect information that can later be uploaded to online databases (as in many technologies used for Type II data collection activities). Technologies used for Type I land tenure enabling activities all involve providing access to online resources, while technologies used for Type III titling activities involve interfacing with online land registration databases. Eleven technologies make use of GPS tools for Type II data collection activities, including accessing satellite data or using handheld GPS devices to map property boundaries.

Many land tenure technologies are used for activities targeting specific groups of landholders. The most commonly targeted population groups include low-income (9), rural (9), women (8), and indigenous (7) populations, however other target populations include smallholder farmers, policy makers, and urban populations, and five technologies target "developing countries" broadly defined. Eleven either do not specify a target population or state that they generally target the public or any individual interested in the technology.

We find little public data on costs associated with developing or using land tenure technologies. Though nine technologies make use of fees charged directly to clients, no sources provide specific details of the exact costs.

While our review focused on technology characteristics, we also identified some initial information on the implementation of these technologies. Many operate on a global scale (9 out of 38), however of the technologies that have been developed and implemented to target specific regions, most target Sub-Saharan Africa (8) followed by Latin America (4) and Southeast Asia (4). Implementation of technologies for Type II (Data Collection) activities is most widely spread, with examples from North and South America, Latin America, Sub-Saharan Africa, the Middle East and North Africa, Southeast Asia, and Oceania. Technologies are also used for Type III (Titling) activities across many regions as well, but in a smaller number of countries. In contrast, technologies used for Type I (Enabling) activities are only in Sub-Saharan Africa and Southeast Asia.

We find initial evidence of impacts from the implementation of 18 of 38 technologies, though this evidence is largely limited to direct outputs of technology implementation. The three outputs that are most widely reported are number of communities or parcels mapped (from Type II activities), the number of titles or certifications issued (from Type III titling activities), and efficiencies achieved. We also find some evidence of cost efficiencies achieved, from the perspective of land tenure system administrators – mostly government bodies). We also find evidence of implementation challenges for 16 of the 38 land tenure technologies. Of these challenges, an inability to collect up-to-date or accurate information is the most commonly reported (6 technologies), affecting both Type II land tenure data collection activities and Type III titling activities (which apply information aggregated in Type II activities).

Introduction

Land tenure refers to a set of land rights and land governance institutions which can be informal (customary, traditional) or formal (legally recognized), that define relationships between people and land and natural resources (Lawry et al., 2017). These land relationships may include, but are not limited to, rights to use land for cultivation and production, rights to control how land should be used including for cultivation, resource extraction, conservation, or construction, and rights to transfer – through sale, gift, or inheritance – those land use and control rights (Feder & Feeny, 1991). The Global Land Tool Network (GLTN) (2015) defines land tenure as a continuum, where customary or informal land rights fall at one end of the spectrum and formal, legally registered land rights fall at the other end. Customary or informal land tenure systems consist of land use rights that are recognized by indigenous populations, ethnic or religious groups, individual communities, or other non-state actors, with the support of institutions created and governed by those non-state actors to manage land resources (Huggins, 2012; FOLA, n.d.). Formal land tenure systems, in contrast, refer to legal rights (often in the form of titles) allocated to individuals and/or communities to access, use, control, and transfer land, along with the state-managed land administration processes that govern those legal rights (FAO, 2002). Informal land tenure rights and governance processes may or may not have formal (legal) recognition (Lawry et al., 2017).

Land tenure security is defined by the FAO (2002) as "the certainty that a person's rights to land will be recognized by others and protected in cases of specific challenges" (p. 18), and depends on systems to enforce land rights and exclude others from challenging them (Feder & Feeny, 1991). When land resources are relatively abundant landholders may enjoy some *de facto* land tenure security even in the absence of *de jure* land rights, so long as the land resource remains uncontested. In other instances existing customary land tenure systems may be sufficient to ensure land tenure security (and support sustainable land management and investments in land productivity) for participants within the system (Atteh, 1985; FAO, 2002; Lawry et al., 2017). However, when competition for scarce land resources increases, or when there are more people in a given locality than a customary land tenure system is able to support, conflicts may emerge or customary land tenure systems can break down, leading to land insecurity (Holden & Otsuka, 2014). Conflict may also emerge when there are multiple land tenure systems among neighboring communities – leading to potential disputes owing to differences across neighboring tenure systems (Udry, 2011). The presence of multiple different land tenure systems within a country can also pose costs and administrative burdens for central governments, or lead to uncertainty surrounding formal land rights definition and enforcement (Simbizi et al., 2014).

In low and middle income countries increased land tenure security has been linked to improved land management including increased investment in land improvements and capital supporting agricultural productivity (Deininger & Jun, 2006; Deininger, Ali, & Alemu, 2011; Ali, Deininger, & Goldstein, 2014; Lawry et al., 2017). When land users have secure land rights, they are more likely to incorporate longer time periods and sustainability into their land use planning, and are more likely to invest in land improvements and production technologies (Tenaw, Islam, & Parviainen, 2009). Yet in spite of the widely recognized benefits of land tenure security more than 70 percent of the world's population lack access to formal systems to register their property and receive land titles (Enemark, Bell, Lemmen, & McLaren, 2014). Land tenure insecurity is particularly acute among women, remote, poor, and vulnerable populations: a wealth of research across multiple low-income countries has suggested women often gain rights to land primarily through their relationships with men, and hence tend to have weaker land rights, limiting their tenure security (Gray & Kevane, 1999; Yngstrom, 2002; UN Women, 2012; Holden & Ghebru, 2016; Mitchell et al., 2016; Ghebru & Lambrecht, 2017). And in Sub-Saharan Africa there is some evidence that women have been excluded both from customary land tenure arrangements and from increasingly formalized land tenure systems (Place, 2009).

Today many countries are working to reform their land tenure systems (Rekha, 2012) to be more inclusive and to realize the economic benefits associated with more secure land tenure. These reform efforts often involve applying new technologies to either formalize existing customary land tenure systems or to develop new formal land tenure systems. One major challenge to ensuring land tenure security involves collecting and administering information on land, people, and their rights (FAO, 2002). In customary tenure systems, information on landholder pre-existing land rights may not be written down or may consist of informal "proofs" accepted by the community but not accepted by government administrators as legal land rights documents (*Ibid.*). In formal systems, information on rights is often recorded in some form of land registration system, but registration systems may be incomplete, poorly-integrated, or inaccessible to certain populations or users (Lawry et al., 2017). The use of technology can simplify data collection, property registration, and record management, and has the potential to reduce the costs and time associated with delivering land titles (Allen, 2014). Incorporating technology can help individual land users and communities to accurately measure and record their land boundaries and in some cases to apply for land titles, and can help governments manage land records to increase transparency and deliver better services to land owners (*Ibid.*). Using technology to improve land administration systems, therefore, can reduce government costs and may reduce conflicts among existing landholders and between landholders and new land buyers (Enemark et al., 2014). Receiving formal legal documentation can lead to further financial opportunities such as access to credit (Rekha, 2012) and such land tenure formalization is also proposed as supporting efficient land markets (FAO, 2002). Therefore technology may make it easier for landholders in both customary and formal systems to realize more secure land tenure, as well as some of the associated benefits.

A preliminary review of literature indicated that new technologies are implemented to support three main types of activities related to supporting land tenure security. These include:

- ***Type I (Enabling) – Support for Land Tenure Enabling Environment***: Technologies used for "enabling" activities provide services that either clarify and distill a country's existing regulatory framework to landholders, or provide legal guidance and tools for landholders to utilize. Many landholders lack information regarding formal aspects of their land tenure, and these databases aim to create transparency to highlight the vulnerability of marginalized communities and facilitate landholders' ability to protect their lands from potential external land acquirers (LandMark, n.d.).
- ***Type II (Data Collection) – Land Tenure Data Collection and Aggregation***: Technologies can support land tenure systems by collecting and aggregating information on existing land rights. Many technologies collect new data on landholders and holdings through surveys, GPS data, and satellite or aerial imagery. Other technologies aggregate existing data and information on landholders and holdings, including drawing on spatial data and digitizing land records and formal and informal tenure documents. Drawing on pre-existing and/or newly collected data, technologies engaged in "data collection" activities aim to aggregate and organize data into maps and databases that document existing land tenure, supporting tenure security for landholders and land administration by governments (Allen, 2014).
- ***Type III (Titling) – Formal Land Titling:*** Some technologies can help landholders apply for legal land titles and certifications to secure more formal land tenure. Many of these technologies partner directly with government agencies to ensure that landholders are able to comply with legal titling requirements and successfully receive and transfer land titles (USAID, 2017; LandMapp, n.d.), supporting tenure security for landholders and improving efficiency of land rights administration for governments.

This report does not review all technologies associated with land tenure, but instead focuses on the technologies that are associated with the systems by which landholders and governments access information about land rights policies and processes, develop accurate and legally recognized data and maps on landholding and tenure status, and obtain legal title and/or rights to occupy, use and transfer rights to land. We begin with

a summary of our methodology for identifying 38 technologies used for the three types of land tenure activities. Next, we summarize the main characteristics across technologies implemented for each of the three types of land tenure activities. We then review available information of the implementation of these technologies. Though the focus of the review is on information about the technologies themselves and not on the various projects that may be applying them, we report initial findings on the geographies and populations served by projects using these 38 technologies, relevant cost information, and their reported impacts and outcomes. In addition, we also present case studies on selected technologies as an Appendix.

Methods

The goal of this review was to identify and analyze innovative technologies that aim to support land rights and land administration processes for individuals and communities. To identify these technologies, we conducted searches on Google and Google Scholar using the following search string:

- ("land rights" OR "land tenure") AND (technology OR software OR program OR platform) AND (map OR records OR mapping OR digital OR digitize)

We also conducted a series of supplemental searches, modifying this search string by adding specific terms for target geographies and populations, including Africa, Latin America, South America, Asia, women, and gender. Search results are summarized in Appendix A.

We identified two broad categories of technologies that organizations may use as part of land tenure activities and projects: technologies specifically created for land rights uses, and multi-purpose technologies applied to land rights uses. This report primarily summarizes the first category, which are devices and software applications designed to explicitly serve a land rights purpose, including enabling (Type I), data collection (Type II), and titling (Type III). However, we describe certain relevant multi-purpose technologies when they are connected with a land tenure technology or employed in the process of documenting land rights.

Multi-purpose technologies are not designed or created specifically for land rights purposes. Instead, these technologies offer tools such as spatial data collection, storage, mapping, and navigation functionalities intended to serve a variety of project needs. They can often be used immediately or “off-the-shelf” to support a land rights project. Examples of multi-purpose technologies include devices such as drones and handheld GPS units, or software applications such as GeoODK and technologies such as Blockchain. We do not analyze each of the multi-purpose technologies identified during our review, however we do capture when these technologies are used in conjunction with a land tenure technology. Appendix B presents a table of 12 multi-purpose technologies identified through our searches, along with a brief description of how each technology is used in the context of land tenure security.

Table 1 presents the 38 land tenure technologies identified in our searches and summarized in this report, noting the types of activities supporting land tenure associated with each.

Table 1. Summary of Identified Land Tenure Technologies

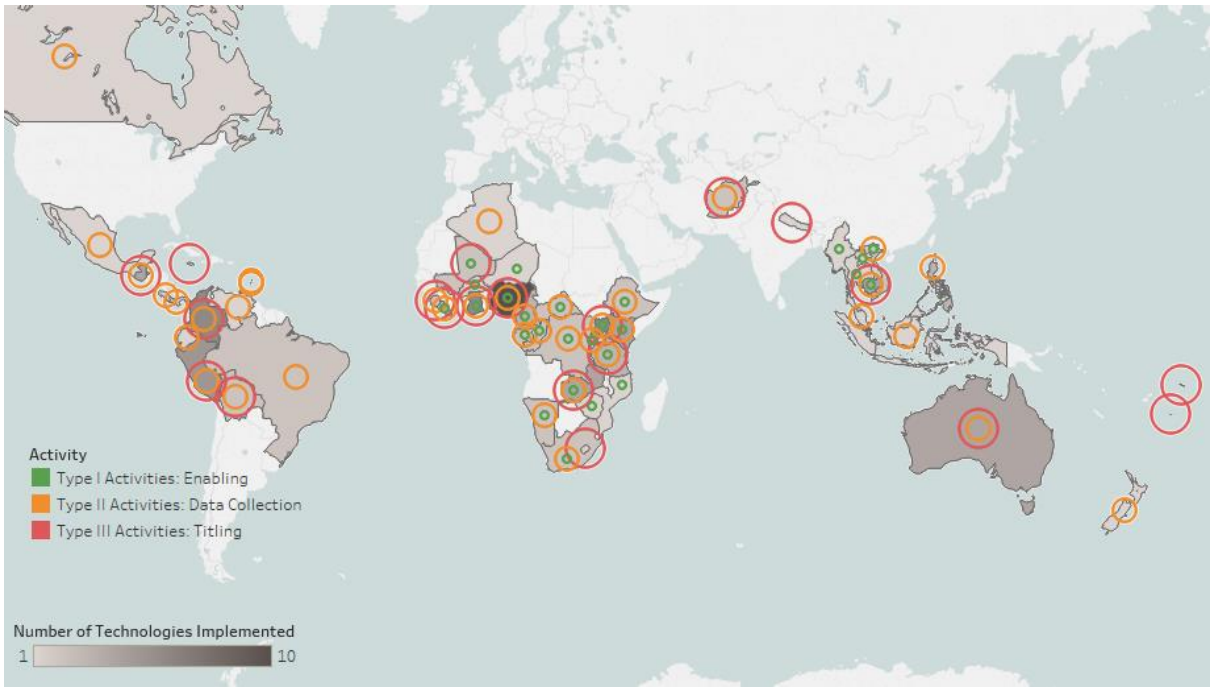
Technology	*Target or Implementation Geographies*	*Platform*	*Intended Users*	*Land Tenure Activities*
Aumentum Cadastre	Americas, Asia Pacific, Middle East, North Africa, SSA	Computer - desktop	Governments	Types II, III
Aumentum OpenTitle*	Afghanistan, Liberia, Ghana, Sierra Leone	Computer - desktop; computer - internet	Governments and their implementing partners (e.g., NGOs); rural, low-income communities	Types II, III
Aumentum Registry	Americas, Asia Pacific, Middle East, North Africa, SSA	Computer - desktop/application	Government Agencies	Type III
Blockchain (BitFury)*	Piloted in Honduras, Sweden, Republic of Georgia	Internet accessible database	National Governments	Type III
Cadasta Platform*	Africa; Europe; LA; SA; SEA; United States	Computer - desktop; computer - internet	Organizations and communities	Type II
Focus on Land in Africa (FOLA)	Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Liberia, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, South Africa, Tanzania, Uganda, Zambia, Zimbabwe	Computer - desktop; mobile phone - smart	Not specified	Type I
Gender and Land Rights Database	Global: for list of countries see http://www.fao.org/gender-landrights-database/country-profiles/countries-list/en/	Computer - desktop; mobile phone - smart	Government Agencies	Type I
Geodata Cadastral Database	Evidence of projects in Australia, Philippines, Vietnam, and U.S.	Computer - desktop	Governments and Private Business	Type II
Global Forest Watch: Land Rights	Evidence of projects in Australia, Brazil, Canada, Costa Rica, Mexico, New Zealand, Panama	Computer - desktop	Indigenous groups	Type II
Innola Solutions	Not specified	Computer - desktop	Not specified	Type II III
Its4Land	Ethiopia, Kenya, Rwanda (still in pilot phase)	Computer - internet	Urban and rural Smallholders; Pastoralists; Rural landowners	Type II
Land Matrix	Low and Middle-Income Countries (World Bank classification)	Computer - desktop	Not specified	Type II
Land Portal	Global	Computer - desktop; mobile phone - smart	Not specified	Types I, II
Land Registration as a Solution	Australia	Computer - desktop	Government agencies	Types II, III
Land Resource Manager	Global	Computer - desktop	Businesses with land assets	Type II
Land Rights Platform	Cambodia (specific)	Computer - desktop; mobile phone - smart	Cambodian youth	Type I
Land Use Planning for Tenure Security	Not specified	Computer - desktop/application; mobile - smart	Rural and Urban Poor	Type I

Landfolio Software	Global	Computer - desktop	Compliance monitoring agencies for natural resources (i.e., mineral extraction, surface and water rights)	Type III
Landmapp*	Ghana; plans to expand in West Africa and SEA	Mobile phone - smart	Rural smallholder farmers	Types II, III
LandMark	Global	Computer - desktop	Indigenous groups	Type II
Landwise	Asia, Eastern Europe, Latin America, Middle East, North Africa, SSA	Computer - desktop; mobile phone - smart	Lawyers, researchers, and development practitioners	Type I
Mapping for Rights*	Peru; SSA	Internet accessible database; mobile app - smart phone	Indigenous and forest-dependent people	Types I, II
Mobile Application to Secure Tenure (MAST)*	Piloted in Burkina Faso and Tanzania	Computer - desktop; mobile phone - smart	Rural land claimants	Types II, III
mLocGov	Mali, Nigeria	Computer - desktop/application; computer - internet	Governments and small holder farmers	Type III
Mobile DHIS2 Tool	Eastern Zambia	Mobile phone - feature	Not specified	Types II, III
Mobineo	Kenya	Computer - desktop	Governments	Type II
One Map Initiative*	Indonesia	Computer - internet	Indigenous or rural groups	Type II
Open Development Initiative	Mekong region: Cambodia, Laos, Myanmar, Thailand, Vietnam	Computer - desktop; mobile phone - smart	NGOs (e.g., universities)	Type I
RAISG	Amazonia - Bolivia, Brazil, Colombia, Ecuador, Peru and Venezuela	Computer - desktop	Indigenous peoples	Type II
Red Tierras*	Bolivia; Colombia; Guatemala	Computer - desktop	Rural, low-income communities	Types II, III
Sarawak Geoportal	Sarawak, Malaysia	Computer - desktop	Indigenouse Sarawak peoples	Type II
Sistema de información sobre comunidades nativas de la amazonía peruana (SICNA)	Peruvian Amazon	Computer - desktop	Indigenous Amazonians	Type II
Social Tenure Domain Model (STDM)*	Africa; Caribbean; Colombia; Philippines	Computer - desktop/application	Land insecure poor	Type II
SOLA Community Server	Not specified	Computer - desktop	Not specified	Type III
SOLA Open Tenure	Evidence of projects in Cambodia, Guatemala, Nigeria, Uganda	Computer - desktop	Not specified	Type II
SOLA Registry	Evidence of projects in Ghana, Nepal, Samoa, Lesotho, Tonga, Nigeria	Computer - desktop	Government agencies	Type III

SOLA Systematic Registration	Piloted in Nigeria; other geographies not specified	Computer - desktop/application; computer - internet	Not specified	Types II, III
Suyo*	Piloted in Bolivia; Colombia	Mobile phone - smart	Low-income families in informal settings	Types II, III
Talking Titler	Evidence of projects in Algeria, South Africa (a village in SA) and Lagos, Nigeria	Computer - desktop/application	Governments	Type II
The Tropical Forest Community Mapping Initiative (TFCMI)/Mapping for Rights	Cameroon, Central African Republic, Congo, Democratic Republic of the Congo, Gabon, Ghana, Peru	Computer - desktop	Indigenous and forest-dependent peoples	Types I, II

For each technology, we collected information on how they are implemented within land tenure processes and coded this information into a spreadsheet, using the same review framework for each technology. Appendix C includes an outline of this review framework, upon which this report's analysis is based. Appendix D presents a brief summary of each technology reviewed and Appendix E includes tables summarizing the characteristics and implementation of selected land tenure technologies (noted with an asterisk (*) in Table 1).[1]

Figure 1. Map of Geographies Served by Land Tenure Technologies



Note: In addition to the technologies included in the map, we identified nine technologies that describe operating "globally," without listing a more specific target geography. Of these nine, three are applied to Type I activities, five to Type II activities, and one to Type III activities (none are used for more than one type of activity).

[1] Technologies selected for "Profile Summaries" were selected to cover a range of 1) platforms; 2) target geographies; and 3) clients served. More targeted research was conducted on selected technologies with available information reported.

Figure 1 shows the geographies served by each of the land tenure technologies. The map indicates both the number of different technologies within each country for which we find evidence of implementation by land tenure projects (country shading), as well as which of the three types of land tenure activities are targeted by the technologies being implemented in that country (colored circles).

Technology Platforms

In addition to targeting different types of activities related to land tenure security, the 38 technologies reviewed also operate on a variety of platforms including a desktop or laptop computer, mobile smartphone or tablet, or mobile feature phone, though 24 may be accessed on multiple platforms.

All 38 technologies reviewed fall in the *computer-based technology* category involving the use of a desktop or laptop computer, in all cases through software and applications that can be downloaded to a computer or databases accessed via computer. This category also includes technologies that are entirely accessed through the internet using a desktop or laptop computer, such as the Sarawak Geoportal, which is an online interactive mapping portal for the island of Sarawak in Malaysia.

Table 2 shows the number of technologies that involve computer/laptop use by host organizations, client/landholders, and by both in each activity type. Most technologies require some computer use by both landholders and implementing host organizations, but, for Type II activities, the client/landholder does not use computer-based technologies in seven cases, as computer-based tasks are undertaken by the host or implementing organization for these technologies. In three of these cases - Suyo, SICNA, and Landmapp – there is no involvement by clients or targeted landholders in the use of any technology platforms in any activities. In the four other cases, the client/targeted landholder does not use a computer or laptop directly but does interact with the technology through a different platform (mobile). No technologies are operated through a computer platform solely by the client/targeted landholder, and 29 are operated by both the host organization and the client/landholder. Technologies in the "both" category include the Aumentum Suite (Cadastre, OpenTitle, Registry) developed by Thomson Reuters - for example, Aumentum Registry is an administration software that is downloaded from the internet to a desktop computer that can digitize paper records and streamline the land registration process (Thomson Reuters, 2013).

Table 2. Number of Computer-based Technologies by Activity Type and User

	Type I: Enabling	Type II: Data Collection	Type III: Titling	Multiple	Total
Host Organization	8	26	13	11	**36**
Client/Landholder	8	19	12	8	**31**
Both	8	19	12	9	**29**
Total	**8**	**26**	**13**	**9**	**38**

Note: Technologies in multiple categories are double counted and totals represent unique technologies.

Technologies using the *mobile device - smart* platform (22 of 38) offer services that require the use of an internet-enabled mobile phone or tablet, usually by providing a downloadable application. We included in this category any technologies that require an application on a smart mobile device, or any online technology that can be accessed through a smart mobile device. Of the 22 technologies that operate within this technology platform, ten are operated by both the host organization and the client/landholder, one is operated solely by the host organization and 11 are operated solely by the client/targeted landholder (Table 3). An example of a mobile application that helps collect data for land tenure activities is Landmapp. The Landmapp mobile app can be used on a phone or a tablet and provides a package that includes GPS capabilities, maps, and land tenure forms. The technology is targeted toward farmers, and Landmapp surveyors can use the app to map farm boundaries, answer questions, and submit other data. Landmapp then analyzes and verifies the data,

ensures that the land tenure document is signed by the relevant authorities and then delivers the documents to the farmers (Landmapp, n.d.).

Table 3. Number of Mobile (smart)-based Technologies by Activity Type and User

	Type I: Enabling	Type II: Data Collection	Type III: Titling	Multiple	Total
Host Organization	8	3	2	2	**11**
Client/Landholder	8	12	2	1	**21**
Both	8	2	0	0	**10**
Total	**8**	**13**	**4**	**3**	**22**

Note: Technologies in multiple categories are double counted and totals represent unique technologies.

Mobile device – feature technologies (3) include technologies that offer non-internet based mobile phone services, primarily through calls and text. These technologies allow landholders to collect and/or submit information via SMS texts, or to receive information via calls and SMS texts. Because these are basic phone functionalities, landholders with smart mobile phones are also able to access these services, but the technology may be more broadly accessible than those only available on internet-enabled mobile devices. Of the three technologies that operate within this technology platform, two are operated solely by the client/targeted landholder and one operated by both the host organization and the client / landholder (Table 4). For example, the mobile DHIS2 tool developed by Akros allows community members in Zambia to send requests to change, delete, or add new information to parcels in their village through a Java-enabled open source database software for low-cost feature phones, which then allows village officials to record the information and issue customary land certificates (Sommerville, Stickler, Norfolk, & Brooks, 2016). None of the technologies provided via feature mobile devices is used for Type I (enabling) activities, as those activities typically involve provision of resources via internet.

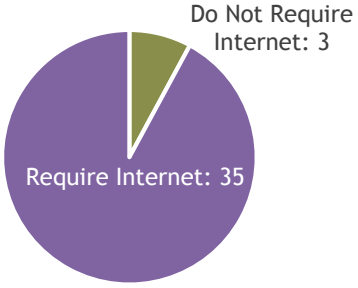
Table 4. Number of Mobile (feature)-based Technologies by Activity Type and User

	Type I: Enabling	Type II: Data Collection	Type III: Titling	Multiple	Total
Host Organization	0	1	1	1	**1**
Client/Landholder	0	2	3	2	**3**
Both	0	1	1	1	**1**
Total	**0**	**2**	**3**	**2**	**3**

Note: Technologies in multiple categories are double counted and totals represent unique technologies.

All of the technologies – primarily tools for accessing land tenure-related data sources – depend on access to internet on both computers and mobile devices. Internet-based technologies include online portals, databases, and maps that can be accessed through a computer, tablet, or phone and require internet access to function (i.e., at least some functions cannot be downloaded and used offline). All 38 technologies in this review depend on internet access for at least some part of their use, and 35 of these technologies require that both the host organization and the client/landholder have access to internet.

Figure 2. Technologies Requiring that Clients/Landholders have Access to Internet



Source: Product websites.

Only three technologies (MAST, Mobile DHIS2 Tool, Red Tierras) do not require that the client/landholder have access to internet. These technologies are employed in Type II and Type III activities, but do not operate in activity Type I. For these technologies, activities or implementation steps requiring internet access are conducted solely by the technology host organization.

An example of a project requiring internet for both the host organization and the client/landholder is The Tropical Forest Community Mapping Initiative (TFCMI)/Mapping for Rights project, which is developing an interactive community map in the Congo Basin, accessible in an online database (Rainforest Foundation UK, n.d.). This technology allows the community to stay up to date on the status of land tenure for specific areas of land and allows the community to submit any changes in status through the internet.

Databases such as TFCMI always require internet to access the tool, but other technologies, particularly those used for data collection or mapping, have offline capabilities integrated into their operation, and can cache information until an internet connection is acquired, and information can be uploaded to a server or the cloud. Landmapp, for example, allows surveyors to collect information required for land tenure applications through the app, and stores the data locally on the app until the surveyor establishes an internet connection, at which time they digitally send the application to the authorizing agency. Cadasta Platform operates in a similar fashion: the technology requires that the user have an Android phone or tablet equipped with Open Data Kit (ODK) and GeoODK software, which are used to collect field data offline. When the user gains access to an internet connection, they can upload the data directly to the Cadasta Platform, which syncs with ODK and GeoODK.

In addition to these computing platforms through which users interface with land tenure technologies, several technologies make use of other tools, primarily for mapping and data collection. One technology (its4land) employs a *drone/UAV* to collect imagery collection and mapping services, which is operated by the host organization. To date its4land has used UAVs as part of a variety of geospatial data collection activities in Rwanda, Kenya, and Ethiopia in support of land tenure recording (its4land, n.d.).

Eleven technologies make use of *GPS* or *geolocation tools*. Eight of these technologies use satellite-based geolocation - these technologies do not necessarily collect field-based GPS information themselves. While 3 out of 8 technologies (Landmapp, RAISG, Social Tenure Domain Model) collect original data using satellite-based systems, the other five use existing satellite data to update, georeference, or overlay spatial data collected using other methods, such as handheld GPS (as in the case of Sistema de Información Sobre Comunidades Nativas de la Amazonía Peruana (SICNA) in the Peruvian Amazon). Three technologies include use of handheld GPS devices to collect on-the-ground GPS information on individual and community lands. One example is work done through Red Tierras, which allows communities such as rural farmers in Bolivia to send GPS points to a central digital repository to map land boundaries.

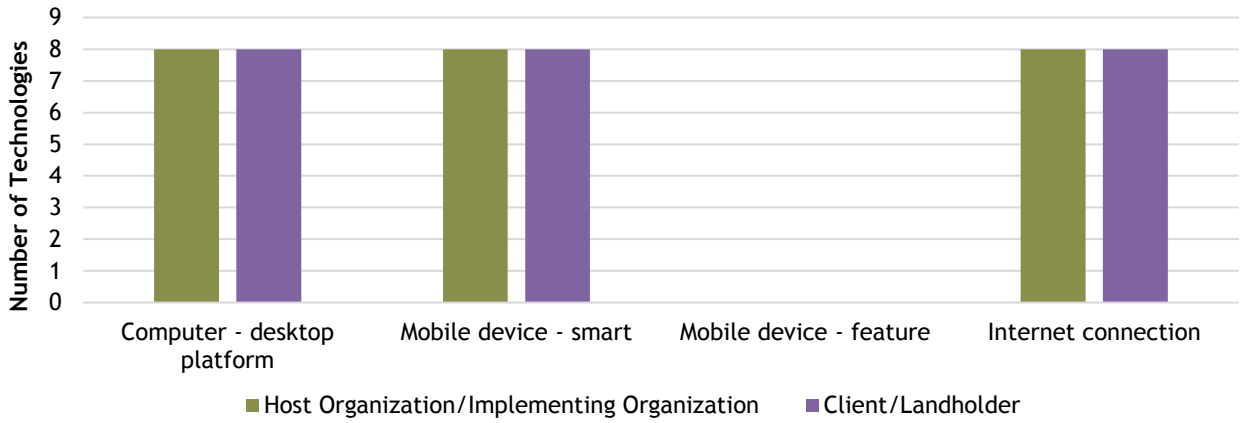
Technologies by Type of Land Tenure Security Activity

We next summarize and analyze the technologies used for each type of land tenure security activity (Type I, Type II, Type III) below. Among the 38 land tenure technologies reviewed 25 only address one primary type of activity, while the remaining 13 are used to support multiple activities. The most common combination of activities for technologies is Type II activities (data collection) in combination with Type III technologies (titling), with 10 technologies engaged in these combined activities. MAST (Mobile Application to Secure Tenure) is the only technology that operates in all three activity types.

Type I – Support for Land Tenure Enabling Environment

Eight (out of 38) technologies provide at least a portion of their services in support of the land tenure enabling environment (Type I activities). For two additional technologies (MAST, mLocGov), although the organizations using these technologies participate in Type I enabling activities, they do not use the technology platforms for these activities. Technologies used for "enabling" activities provide services that either clarify and distill a country's existing regulatory framework to landholders, or provide legal guidance and tools for landholders to utilize. Only one technology (TFCMI/Mapping for Rights) that is used for Type I enabling activities is also used for another activity type (Type II, data collection and mapping).

Figure 3. Platforms of Technologies Used for Type I – Enabling Activities

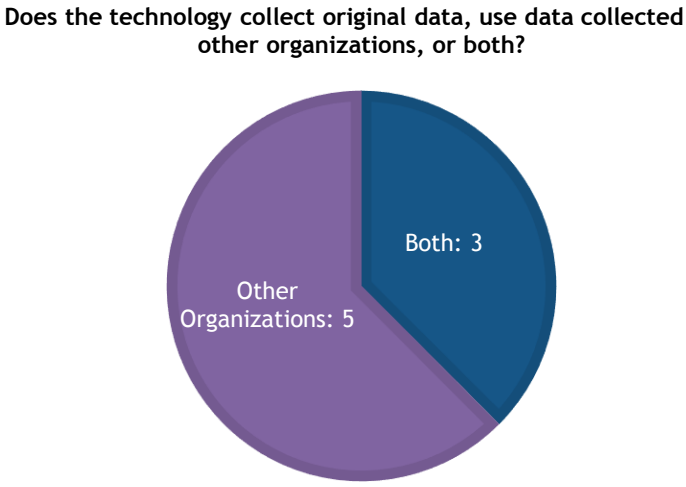


All eight of the organizations identified that use technologies for Type I activities (Focus on Land in Africa, Gender and Land Rights Database, Land Portal, Land Rights Platform, Land Use Planning for Tenure and Security, Landwise, Open Development Initiative, TFCMI) do so through internet-based services that can be accessed through either a computer interface or a smart mobile device (Figure 3). These technologies operate through online databases or portals to provide land tenure resources to landholders, such as legal materials, land-related statistics, and multimedia e-learning videos. There are no technologies that operate on a feature mobile device platform to provide land tenure resources.

Data provided by the various technologies are either collected through the technology itself, as original data, or have been previously collected by outside organizations and then adapted for the technology. For example, Focus on Land in Africa (FOLA) collects original data by crowd-sourcing information on land rights conflicts, but also uses data collected by organizations such as USAID, CGIAR, and the World Bank. All of these data are then made publicly available as a land rights resource in an online database (FOLA, n.d.). Land Portal, on the other hand, only uses data collected by other organizations. It aggregates data collected from partner organizations "[bringing] together resources and data relating to land governance from third parties in one place" (Land Portal, n.d.).

As shown in Figure 4, five out of the eight land tenure technologies used for Type I activities use data collected by other organizations. Three land tenure technologies use both original data and data from other organizations.

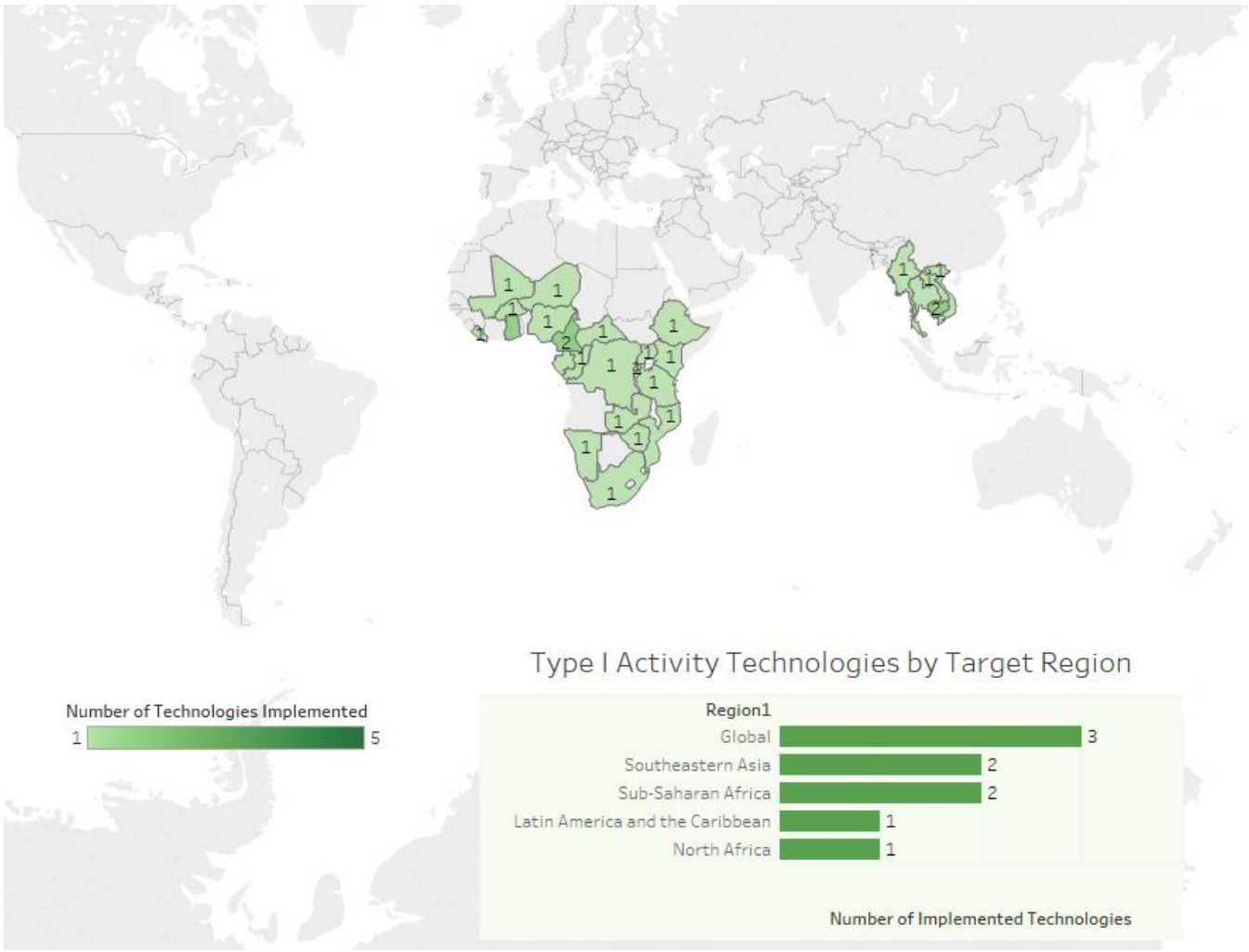
Figure 4. Data Sources and Dissemination in Phase I



Source: Product websites.

Of the three technologies that use both original data and data from other organizations (FOLA, Gender and Land Rights Database, TFCMI), all three note they publicly share the data they collect themselves. For example, the Gender and Land Rights Database provides users access to their data, collected with help from the Food and Agriculture Organization (FAO) and other organizations, through an online database, allowing access to 83 regularly updated country profiles, gender and land-related statistics, and a legal assessment tool. Of the technologies that use data from other organizations (Landwise, Landgate, Land Rights Platform, Open Development Initiative, Land Portal), all six use data sources that were available to the public, including the World Bank, FAO, Global Donor Platform for Rural Development, and Land Matrix.

Figure 5. Number of Type I – Enabling Activities by Country



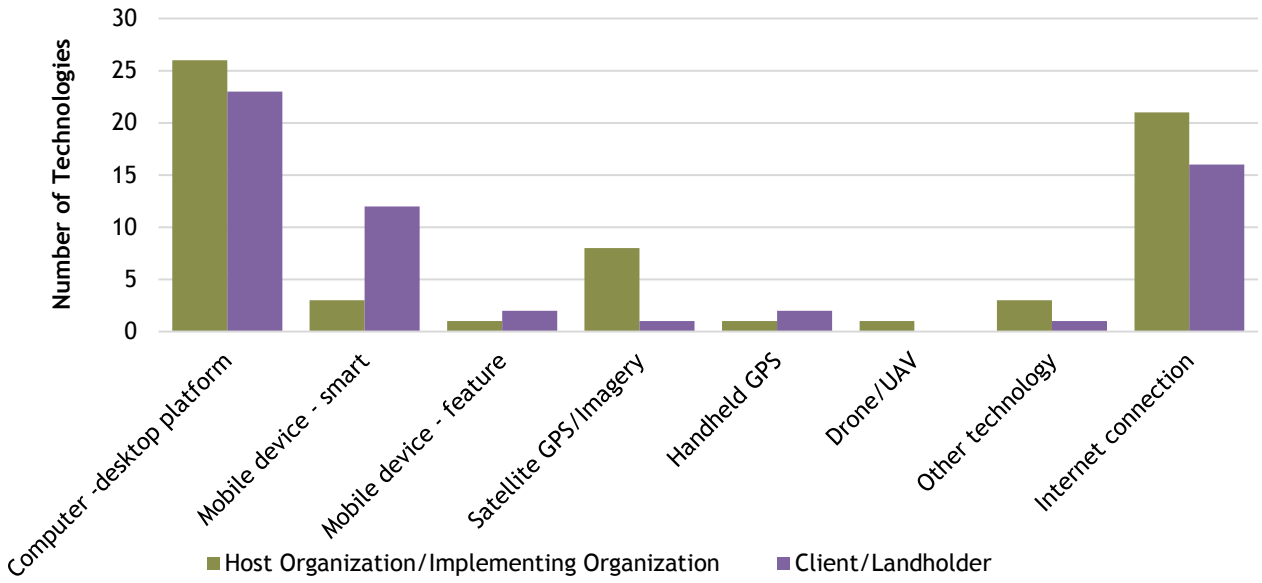
Source: Product websites.

Technologies used for supporting the land tenure enabling environment operate most commonly at a global scale. Many of these technologies are global-level databases containing information for landholders on general land rights policies or laws by country or region. For example, Land Portal hosts information on land governance issues for countries all over the world, with the goal of ensuring "responsible land governance and secure land rights for the world's poor and vulnerable" (Land Portal, n.d.). Though several technologies support the enabling environment for land tenure globally, among technologies we found to operate regionally, Type I activity technologies are the least broadly distributed, spanning only four specific regions. At a regional level, technologies are most commonly employed for Type I activities in Sub-Saharan Africa (FOLA, TFCMI) and Southeastern Asia (Land Rights Platform, Landwise). These regional technologies aggregate data supporting land tenure in their target regions. Of those technologies targeting country-specific projects in Type I activities, all are employed in either Sub-Saharan Africa (23 projects) or Southeast Asia (6 projects). For most countries we only find evidence of one or two technologies being used for Type I (enabling) activities. Cameroon, Ghana, and Cambodia each have projects implementing two technologies for Type I activities, while the remaining countries report one each. Notably, no technologies reported Type I activity implementation in country-specific projects in the Americas, though one, TCFMI, does target the region of Latin American and the Caribbean.

Type II – Land Tenure Data Collection and Aggregation

We found 26 (out of 38) land tenure technologies that use a technology platform to support Type II data collection and aggregation activities. Drawing on pre-existing and/or newly collected data, technologies engaged in "data collection" activities aim to aggregate and organize data into maps and databases that document existing land tenure, supporting tenure security for landholders and land administration by governments (Allen, 2014). Fourteen of these technologies only undertake Type II activities while 12 of the technologies that engage in mapping and data collection also engage in at least one other type of land tenure activity. Figure 6 illustrates the breakdown of technology platforms for the technologies that operate in Type II.

Figure 6. Platforms of Technologies Used for Type II – Data Collection Activities



Source: Product websites.
Note: 18 of the 26 technologies in this activity type use multiple platforms.

For 14 of the 26 technologies, the only technology platform the host organization uses is a desktop or laptop computer. These technologies include Cadasta Platform, where the host organization only manages an online database where clients/landholders upload spatial data, and SOLA Systemic Registration, for which the host organization only provides the software and assistance through the internet. Conversely, 8 of the 26 technologies use solely desktop/laptop computers from the client/landholder side. For example, Social Tenure Domain Model provides spatial data for the client/landholder to access. Another scenario for which only desktop/laptop computers are used includes technologies that collect land tenure data without using additional spatial data collection tools, such as Talking Titler, which stores data such as "titles, deeds, survey plans, descriptive documents, audio records or oral testimonies, videos, photographs, valuation records, etc." (University of Calgary, n.d.).

There is a marked difference in the usage of smart mobile devices between host organization (3) and clients/landholders (12) engaging in Type II (data collection) activities. Among the 12 technologies where clients/landholders use smart mobile devices to collect data, in two cases users download an application onto a smart mobile device to upload and access data, in another two cases users use smart mobile devices to directly

collect spatial data, and in the eight remaining cases users can use a smart mobile device to access a database or portal on the internet to upload and access data.

Type II activities can also include the use of complementary technology platforms that are used to collect spatial data, such as satellite based systems, handheld GPS, and drone/UAV technology. Satellite technology is used more by host organizations (8) compared to clients/landholders (1).

The "Other technology" platforms include its4land's use of smart sketchmaps and TFCMI/Mapping for Rights' use of satellite modem transmitters. The its4land smart sketchmap tool "automates the digitization process for extracting both the spatial and non-spatial aspects of the information in a sketch map, and integrates that data with an underlying base map" (Bennet et al., 2017). Community members and indigenous organizations that use TFCMI/Mapping for Rights use the satellite modem transmitter to submit GPS data from a tablet or smartphone onto an online repository.

In Type II data collection activities, the data collected and aggregated through the technology are again either collected by the technology itself, as original data, or collected by outside organizations and then aggregated by the technology. For example, the Suyo tool is used to collect original data by mapping land boundaries and aggregating other relevant landholder data using a software application and tablet. The Landmapp tool is a tablet- or smartphone-based application that surveyors from Landmapp use to collect data on smallholders' land. The tool collects data either by connecting to a global navigation satellite system (GNSS) device (Emlid Reach RS has been beta tested) to map GPS coordinates of the land boundaries, or by organizing and storing oral data from land holders, which are then corroborated by neighbors. Aumentum Cadastre, contrastingly, does not collect original data – instead it aggregates previously collected data, including parcel maps and other tenure data, into a single cadastral map using coordinate geometry and conflation tools (Thomson Reuters, n.d.).

As shown in Figure 7, only 6 out of the 26 land tenure technologies engaged in Type II activities rely solely upon data collected by other organizations, while 10 technologies collect and distribute original data, and 10 others use both original data and data from other organizations.

Figure 7. Type II Data Sources and Distribution

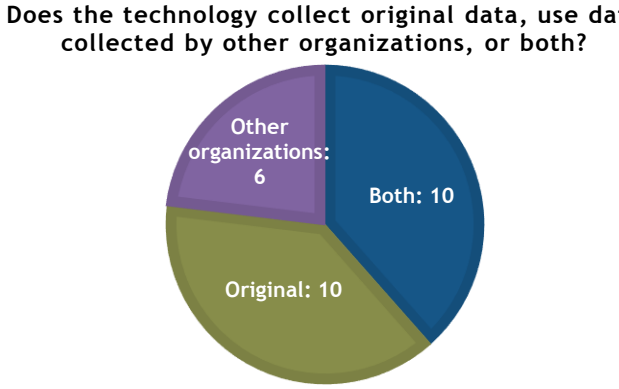
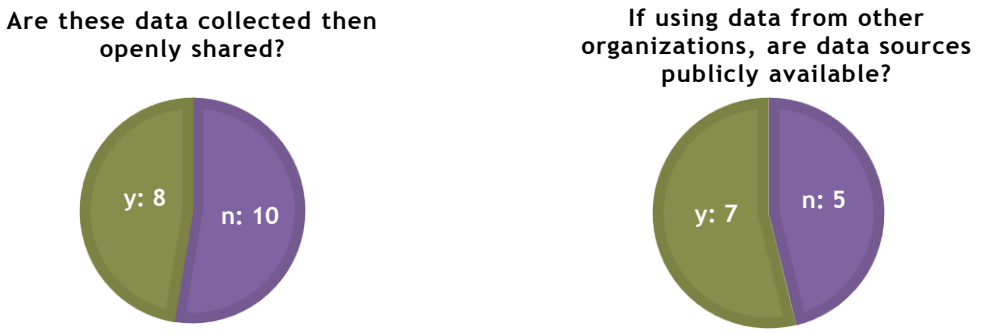


Figure 7 continued

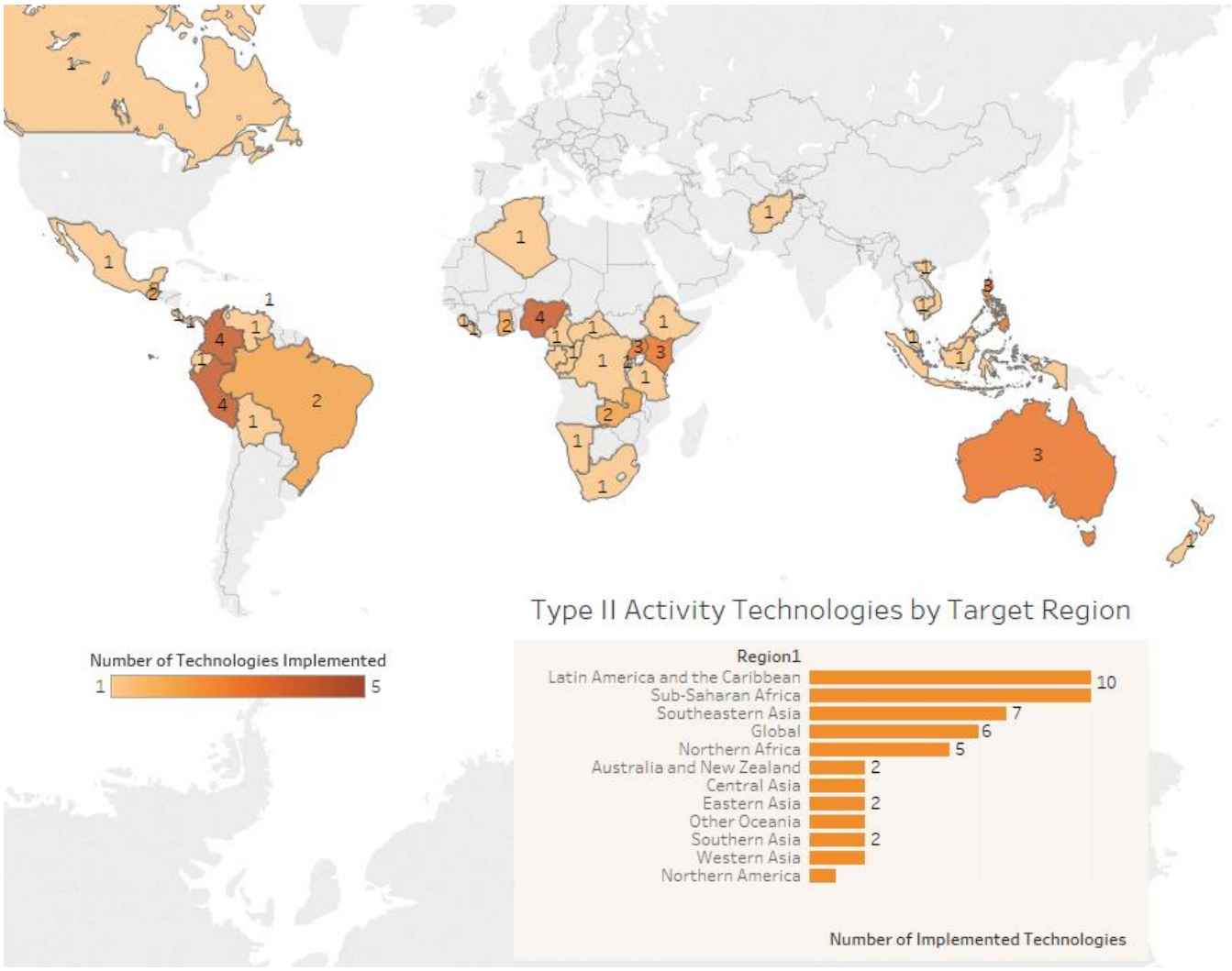


Source: Product websites.
Note: Two technologies, MAST and Land Resource Manager do not mention if their collected original data is openly shared. Four technologies, Aumentum Cadastre, Mobineo, SOLA OpenTenure, and LRaaS do not mention if their data from other organizations is publicly available.

Of the 20 technologies that generate original data, 8 openly share these original data with the public. For example, MAST shares the data collected by a community through its mobile application with the entire community, to facilitate boundary consideration and dispute resolution (USAID, 2017). Landmapp, on the other hand, does not openly share data: the boundary and tenure information collected using the tool are made available only to the client and to the government agencies to whom applications are later submitted (Landmapp, n.d.).

Of the 16 technologies that use data from other organizations, five use data sources that are not public (i.e., proprietary data sources including government land records and map layers, research conducted by organization partners, and other administrative data), while seven use data sources that are available to the public, primarily base maps for georeferencing, including OpenStreetMap, Google Earth and Digital Globe satellite data. Other open data sources used in Type II include media reports and information on large-scale land acquisitions.

Figure 8. Number of Type II – Data Collection Activities by Country



Source: Product websites.

As Figure 8 shows, technologies employed in Type II activities are used in the widest range of geographies, spanning 11 regions globally. These technologies operate most commonly in Latin American and the Caribbean and in Sub-Saharan Africa, with 10 technologies targeting each region. Type II data collection technologies are also commonly employed in Southeastern Asia (7) and globally (6). Of those technologies reporting country-specific projects, these projects are most densely concentrated in Sub-Saharan Africa and Latin America and the Caribbean. Colombia, Peru, and Nigeria have the highest number of projects using Type II technologies, with four each. Kenya follows, with three projects. Technologies targeting only the region of Latin American and the Caribbean are most frequently employed in Type II data collection activities (4). Red Tierras is an example of a technology that operates solely in Latin America and the Caribbean, implemented in projects in Colombia, Bolivia, and Guatemala, through Type II activities. Red Tierras equips landholders with feature phones, and "the SMS technology allows communities to send GPS points (which have previously been recorded on GPS units) to map land boundaries, stay informed about the status of land agreements, and produce the reports required by the government's titling agency. Using Frontline SMS, open-source software, [the] system allows for large scale one- and two-way communication to broadcast key information to land users and to spur discussions between them" (Mercy Corps, 2013).

Type III – Formal Land Titling

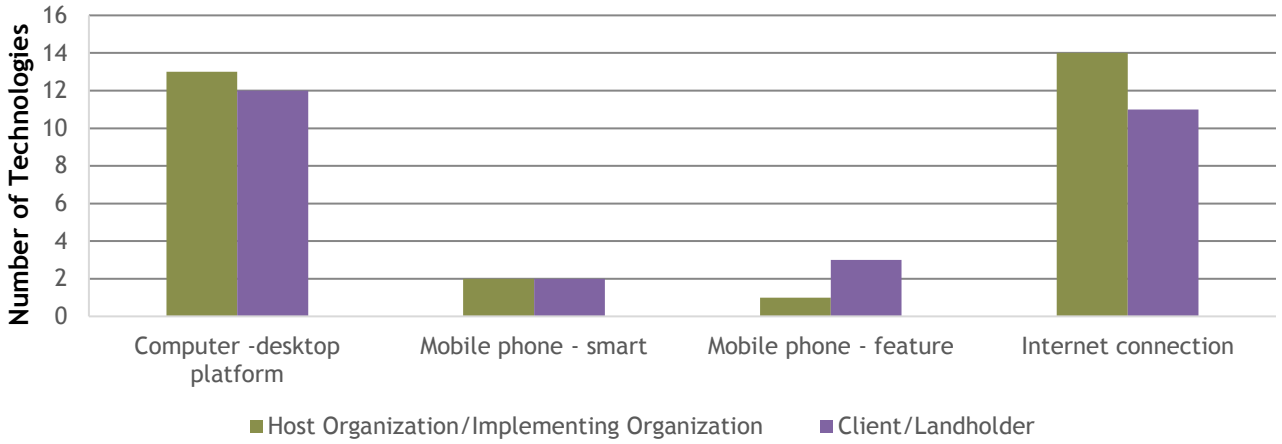
Type III land tenure technologies facilitate the process of landholders registering their holdings with government administrators and receiving confirmation of their rights through titles and other land rights certificates. Examples of technologies issuing less “formal” titles include SOLA Community Server and the Mobile DHIS2 Tool. SOLA Community Server is used by a designated "Community Recorder" to upload details regarding the community's land tenure. The details can then be reviewed and discussed by community members, and "community recognized" tenure rights are published, and titles generated. The Mobile DHIS2 Tool allows designated community members to document changes to land tenure claims, or other related land transactions, via the tool. These claims are then sent through SMS to the local Land District Alliance, allowing the local chief to print and deliver customary land certificates.

Allen (2014) argues that formal land titling may pose potential challenges, such as creating land administration systems that are too expensive or complex for countries to effectively operate, or being inappropriate for indigenous communities – especially nomadic communities – which may disempower them or disrupt their lifestyles. Nevertheless, formal land titling is an important part of land tenure reform efforts in many countries as this is seen as providing more secure land tenure for landholders and facilitating land administration by governments (Rekha, 2012). Many technologies partner directly with government agencies to ensure that landholders are able to comply with legal titling requirements and successfully receive and transfer land titles.

Out of the 16 technologies used to address Type III titling activities, nine are government-oriented, three are landholder-oriented technologies, and four are oriented toward both government clients and landholders. We define government-oriented technologies as those pertaining primarily to land administration and reducing the costs of land titling. One example of a government-oriented technology is mLocGov, which is targeted towards local authorities to integrate “solutions for land management, inventory and management of commercial and non-market assets, development of local development plans, succession and collection of taxes and royalties, and interaction solutions and services and communication with citizens” (Manobi, n.d.). In contrast, landholder-oriented technologies primarily support landholders in submitting applications for land titling. One example is Suyo, which targets low-income families in informal settlements to document information in a mobile app and submitting an application to proper authorities. Some technologies target both government and landholder clients, such as Landfolio, which is a government land management system that also seeks to facilitate applications for the landholder.

Four of the 16 technologies used for Type III titling activities (Aumentum Registry, Landfolio Software, SOLA Community Server, SOLA Registry) work solely in this activity type. One technology (mLocGov) also works in Type I (enabling environment) activities by gathering information on land tenure security in rural communities and help establish land resource management conventions, but only uses technology platforms for Type III activities (Traore, 2015).

Figure 9. Platforms of Technologies Used for Type III – Titling Activities

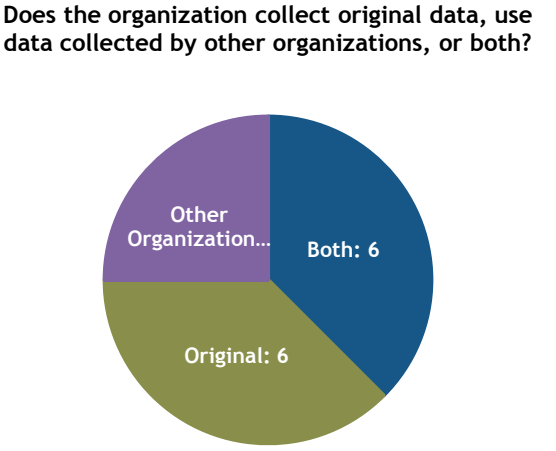


Source: Product websites.
Notes: 3 out of the 16 technologies in this activity type use multiple platforms.

The most used technology platform in this activity type is the desktop or laptop computer, by both host organizations (13) and client/landholders (12). For computer application platforms, the technology is frequently used to store the title information once formal land title certifications are received. For example, SOLA Registry includes a database the stores titles and land record information. The database is integrated with a systematic registry system that automates land title transactions. Internet-based services are also used to submit land title applications and allow landholders to check up on the status of their application. The six technologies that operate via either smart or feature mobile phones (Innola Solutions, Landmapp Project, MAST, Mobile DHIS2 Tool, Red Tierras, Suyo) submit information collected during Type II activities through these platforms, including verified land boundary and claimant information, in support of land title applications.

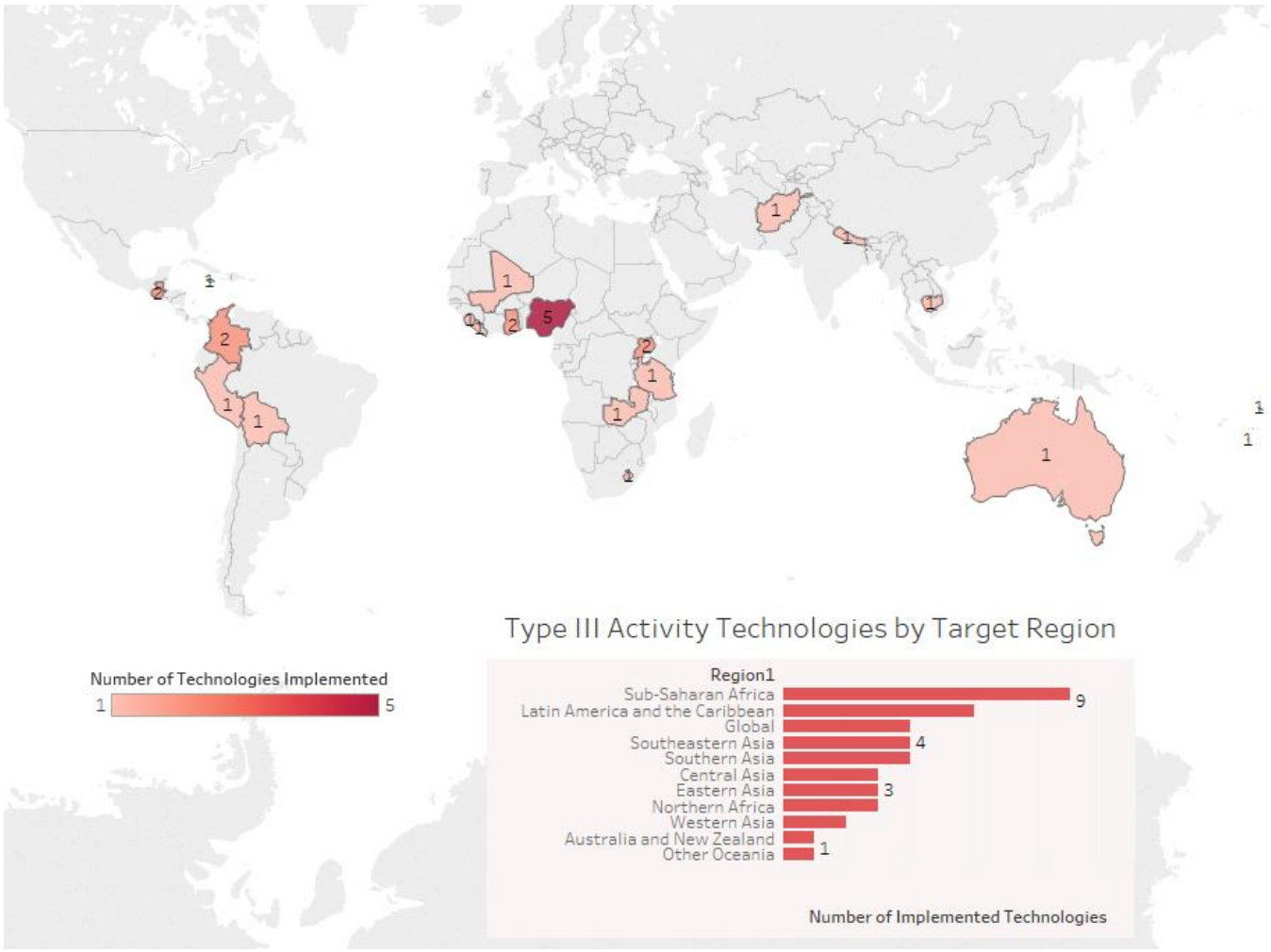
Figure 10 summarizes the data sources used for technologies engaged in Type III activities. Six out of the sixteen technologies operating in Type III activities only use data collected originally, during Type II activities. Six others both use originally collected data and use data collected by other organizations, and four use only data collected by other organizations to submit and distribute land title applications. Landmapp uses both original data, collected during Type II activities using the mobile applications and a tablet, and government map layers and satellite data to corroborate tenure information, and complete and submit land title applications for their clients. An example of a technology only employing original data in Type III activities is the Suyo tool in Colombia, which allows Suyo surveyors to collect information on informal settlements in urban areas of Colombia. Photos of property, ownership history, testimonials from neighbors and friends, utility and tax receipts are gathered during Type II activities, and then used to prepare applications for formal titling.

Figure 10. Phase III Data Sources and Distribution



Of the technologies using original data, either on its own, or in conjunction with data from other organizations, no technologies report that collected data was openly shared. Additionally, of those technologies using data from other sources, none report that their data sources were publicly available. Phase III involves the submission of applications for land titles, so it could follow logically that this information is less likely to be made public. Often, as with the Aumentum suite of software, users are able to change privacy setting to control who has access to this information at this phase. Similarly, in technologies such as Suyo and Landmapp, where surveyors employed by the technology developed are hired by the client, application information is only shared with the clients themselves.

Figure 11: Number of Type III – Land Registration Activities by Country



Source: Product websites.

As shown in Figure 11, Type III activities are limited primarily to Sub-Saharan Africa (9 technologies), Latin American and the Caribbean (6 technologies) and Southeastern and Southern Asia (4 technologies). Three technologies engaged in Type III, Aumentum Registry, Aumentum Cadastre and Aumentum OpenTitle, also target Central, Eastern, and Western Asia, and Oceania (excluding Australia and New Zealand). Of those technologies reporting their use in country-specific projects, the country with the highest number of projects using land tenure technologies for Type III is Nigeria, with five, followed by Colombia, Guatemala, Ghana, and Uganda with two.

Implementation of Land Tenure Technologies

The implementation of land tenure technologies is often specific to projects and implementers rather than to the technologies themselves, and we did not search for additional information on these projects or implementers. In spite of this, in the following sections we present preliminary findings related to land tenure technology implementation derived from the information we identified when reviewing the characteristics of the identified technologies.

Geographies Served

Based on initial implementation information, most (35 out of 38) of the technologies reviewed specify one or more target geographies where the technology has been or is intended to be implemented. The remaining three technologies do not have a specific target geography (Innola Solutions, Land Use Planning for Tenure Security, Talking Titler). All three of these technologies are software systems that provide a base level of functionality that is intended to be further modified by the user. For example, Innola Solutions is a software for communities to build land administration systems upon, and Talking Titler is a software that people can use to aggregate community information for the purpose of securing land tenure.

Of the 35 technologies that specify a geography, nine target a global scale (three engage only in Type I activities, five only in Type II, and one only in Type III). No technologies targeting a global scale work across multiple activity types – they all target one specific activity. The 26 remaining technologies that do not operate on a global scale target or have been used in a variety of regions and scales. Sixteen of these, described in Table 5, target only one geography. The remaining ten serve two or more target geographies. We identified these target geographies by reviewing technology product websites and identifying projects that have used these technologies in any of the following regions, or language indicating intention to serve these regions.

Table 5. Number of Technologies by Uniquely Targeted Geography

Target Geography	Type I Activity	Type II Activity	Type III Activity	Number of Unique Technologies
Global	3	5	1	9
Sub-Saharan Africa	1	5	5	7
Latin America and the Caribbean	0	4	2	4
Southeast Asia	2	6	4	4
Australia and New Zealand	2	2	0	1
Total	8	22	12	

Source: Product websites.
Note: We found no evidence of technologies solely implemented in North Africa, Other Oceania, Central Asia, Eastern Asia, Western Asia, Northern America, and Southern Asia. Technologies in multiple categories are double counted and roqtotals represent unique technologies.

Sub-Saharan Africa is the most targeted geography, with eight technologies uniquely targeting the region, followed by Latin America and the Caribbean (4) and Southeastern Asia (4). Of the technologies operating across or targeting multiple geographies, the majority (8 out of 11) also operate in multiple activity types. Two similar technologies target both multiple regions and multiple activity types. The Aumentum software suite, developed by Thomson Reuters, includes three software programs that are downloaded from the internet, and work across Type II and Type III activities. The Aumentum suite targets small governments serving rural populations in the Middle East/North Africa, Asia/Pacific Islands, Sub-Saharan Africa, and the Americas (Thomson Reuters, n.d.). The SOLA suite, developed by the FAO, includes four software programs, that all integrate with each other to cover functionalities in Type II and Type III activities. The software was piloted in Ghana, Nepal, and Samoa, and is currently implemented in Samoa, Nepal, Lesotho, Tonga, and Nigeria. The SOLA suite is also available in Arabic, French, and Russian (SOLA, n.d.).

Populations Served

Of the 38 land tenure technologies that we reviewed, 27 specify an intended target population of landholders. The remaining 11 technologies either do not specify a target population (Aumentum Cadastre, Aumentum Registry, Innola Solutions, Land Matrix, Land Portal, Land Registration as a Solution, Land Resource Manager, Landfolio Software) or state that they generally target the public or any individual interested in the technology (Cadasta Platform, Open Development Initiative, Red Tierras). Of the 27 technologies that specify a target population, 11 specify only one type of target population, while the remainder specify two or more specific

target populations. 18 technologies also specify sub-populations in addition to landholders. Table 6 summarizes the populations targeted and the number of technologies that target each group.

Table 6. Number of Technologies Targeting Population Groups

Target Population	Low-Income	Rural	Women	Indigenous Groups	Smallholder Farmers	Urban	Policy - Makers in the Development Community	Youth	Total Number of Technologies
Northern Africa	1	1	2						4
SSA	1	2	5		1		3		12
Latin America and the Caribbean	2	3	1	2		1	1		10
Northern America				1					1
Central/Eastern/Western Asia		1							1
Southern Asia	2						1		3
Southeastern Asia	2		1	1			1	1	6
Oceania	1		1		1		1		4
Global		1	3	1					5
Total	**9**	**8**	**13**	**5**	**2**	**1**	**7**	**1**	

Source: Product websites
Note: Column totals include double-counts of technologies operating in multiple geographies or targeting different populations

Low-income populations and women are the most targeted populations, followed by rural populations, policy makers in the development community, and indigenous groups. Most of the technologies targeting specific populations are employed in Sub-Saharan Africa (12), followed by Latin America and the Caribbean (10). Of those technologies operating in Sub-Saharan Africa, they most frequently target women, followed by low-income populations. Of those operating in Latin America and the Caribbean, technologies most frequently target low-income, followed by rural populations.

While the products that mention their intention to serve rural, low-income, and indigenous groups tailor their products to serve these populations uniquely, the technologies that target women vary in their efforts to support women through their technology's service. Gender and Land Rights Database and Landwise both provide legal materials that aim to strengthen women's land rights. Neither FOLA nor MAST target women in their mission, however they both provide specific support to women through unique services. USAID, through MAST, provides trainings on women-specific land rights issues and FOLA highlights on their webpage projects that they have conducted specifically around women's empowerment. Social Tenure Domain Model, Mobineo, and its4land do not mention how they tailor their services for women, however all three mention that they conduct gender-sensitive analysis when necessary though this is not further defined.

Only two of the technologies that we identified mentioned challenges associated with inclusiveness or equity when providing the product services. MAST notes that while USAID provides women training and education on land rights, men sometimes want to maintain dominance over their property and are unwilling to participate in the MAST program with women equally (MAST, 2017). Global Forest Watch notes that comprehensive maps of community-level land are rare, incomplete, or contradictory, because "official demarcation of lands and resource rights is costly, timely, and contentious….[and] governments lack the will or capacity to carry out field mapping to build national inventories of community land" (Global Forest Watch, n.d.). It therefore it is difficult to include a comprehensive list of these communities in their global database

Costs and Revenues

Technology implementation cost and revenue information was limited, but, to varying degrees, some data were available for 19 technologies. Though nine of these 19 technologies mentioned that fees were charged directly to clients, none gave specific details of the exact cost. We found some limited information on costs by type, including implementation/ administration/ management costs, technology creation costs, general cost/ revenue /funding information, user fees, one-time access fees, subscriptions, and land title or registration costs. Table 7 outlines cost information by cost type and technology.

Table 7. Available Cost Information for Land Tenure Technologies

Cost Type	Number of Technologies	Examples
Mention implementation/administration/ management costs	4	• Land Portal: expenses totaling £7,744 in administration for 2015 • Mobile Application to Secure Tenure (MAST): $1 million launch project; $500 per month for cloud storage fees
Mention creation costs	3	• Land Portal: expenses totaling £20,528 for Data Integration and Platform Development for the year 2015 • Cadasta Platform: Omidyar Network reports committing up to $4,166,667 over three years • Its4Land: €3.9 million endowment from Horizon 2020 ICT-Programme of the EU for developing their suite of land mapping technologies
Mention general costs, revenue, and/or funding	4	• Landmapp Project: In 2016, making approx. $45,000 per month [gross or net, not stated] with expectations to triple; angel investment of $283,000 in 2016; mapping technology is sold to client for a fee (amount not specified) • Mobineo: The University of Minnesota student founders won $500 in a technological innovation contest hosted by their university • One Map Initiative: Threatened by recent state budget cuts • Social Tenure Domain Model: Cost of $300,000 for the piloting ($75,000 – Phase I) and scaling up ($225,000 – Phase II) of the STDM in Uganda; the application is available as a free download at http://stdm.gltn.net/downloads/
Involve user fees	15	• User fees were reported in several forms. Some technologies required the purchase of a specific device or unit, some required a one-time fee to access the technology, and others required the purchase of a monthly or yearly subscription. Many technologies also required the targeted landholder pay the cost of title registration.
Require a one-time fee to access the technology	3	• Costs were not freely available online (Aumentum Suite – all 3 software products, Landmapp)
Require the purchase of a subscription	1	• Wolf-GIS Apex: Personal Monthy Fee: $6.99, Professional Monthly Fee: $19.99, Parcel Reporting: $1.99, Personal Annual $74.99, Professional Annual $219.99 (Wolf-GIS Apex)
Report land title or registration costs	1	• Anyone with claim to a communal land must complete an application and return it along with NAD 25 to the Traditional Authority, which will verify and ratify the application. (Program for Communal Land Development, Namibia)

We identified some additional information on implementation costs for two technologies. The Social Tenure Domain Model (STDM) developed by the UN Habitat Global Land Tool Network (GLTN) and piloted in Mbale, Uganda was developed in two phases, with $75,000 in funding for Phase I (initial pilot) and $225,000 for Phase II (follow up pilot testing scalability)—financing was provided by Cities Alliance Financing. The technology aims to use a participatory mapping process, facilitated by the STDM app, to integrate formal and informal customary land rights. The goal of the pilot was to test the implementation efficacy and scalability of the model to other geographies.

Initially piloted in Tanzania in 2014, and later in Burkina Faso, the Mobile Application to Secure Tenure (MAST) is an open source community-based land tenure mapping and registration application created by USAID and implemented by the Cloudburst Group. The pilot was launched with $1 million funding for the Tanzanian pilot. The project aimed to implement a community-based land mapping and registration process and accomplished this by focusing project resources on training community members and implementing cost sustainable documentation processes. As part of project implementation, MAST absorbed adjudication and documentation costs on behalf of project beneficiaries which amounted to $6.50 per parcel, on average. Once parcels were adjudicated, Certificates of Customary Residential Occupation were issued with paper copies being distributed and digital copies being stored on an Amazon Cloud Server with hosting costs reported at approximately $500 per month.

Though the information was limited, we found basic revenue-related data for two technologies. Advara, the developer of Land Registration as a Solution (LRaaS), was awarded a $140 million contract by Landgate of Western Australia for converting their legacy land registry over to a digital cloud-based land registry. The contract award was to cover a period of at least five years. The LRaaS technology aims to digitize legacy land registries to improve efficiency in land titling and registration. Landmapp, an app-based land registration technology, was reported as earning $45,000 per month with expectations to triple revenue from their operations in Ghana. Landmapp's technology provides mapping and documenting capabilities for smallholder farmers with the goal being to provide a certificate or title. Landmapp collects fees directly from the smallholders though such fees are not specified.

We also identified some information on the funders of land tenure technologies. Technology funders come from categories such as bilateral (13 funders) and multilateral (five funders) government organizations, philanthropic (five funders) and not-for-profit (nine funders) organizations, private for-profit (four funders) organizations, and one venture fund (HERi Africa). Several of these funders provide financing for multiple land tenure technologies. For example, the Omidyar Network invests in six different technologies and USAID funds four technologies. Appendix E provides a list of land tenure technology funders by category.

Reported Impacts of Land Tenure Technology Implementation

Initial evidence of outputs or impacts was found for 16 of 38 land tenure technologies during this initial review. Most evidence of impact was measured in terms of outputs, notably: the number of titles/certificates issued (five technologies) and the number of communities/parcels mapped and digitized (two technologies). We find evidence of efficiencies achieved for four technologies. The evidence found on the impacts/outputs is summarized in Table 8.

Table 8. Impact Categories Reported from Technology implementation

Primary Impact Measure	*Examples of Outputs/Impact*	*Relevant Market and Scale Notes*
Number of Communities/Parcels Mapped and Digitized (5)	• **Aumentum Cadastre:** 16,500 frayed paper land maps digitized within 6 months; 500,000 titles and land administration files digitized	• **Aumentum Cadastre:** ○ Americas, Asia Pacific, Middle East, North Africa, SSA

	• **Aumentum OpenTitle:** 19 communities surveyed; 325 hectares of land receiving documents • **Mobile Application to Secure Tenure:** 55, 39, 72 parcels/day mapped in pilots I, II, and III, respectively • **Suyo:** 1,300 properties formalized in seven communities during pilot in Bolivia • **Tropical Forest Community Mapping Initiative:** Has supported mapping of 300 communities across Congo Basin covering over 2 million hectares	○ Government clients • **Aumentum OpenTitle:** ○ Case studies from Afghanistan, Ghana, Liberia, Sierra Leone ○ Targets rural, low-income communities • **Mobile Application to Secure Tenure:** ○ Piloted in Burkina Faso, Tanzania ○ App is highly adaptable to facilitate replicability ○ Plans to scale to other West African and SE Asian countries • **Suyo:** ○ Piloted in Bolivia; current implementation in Colombia (Barranquilla, Bogotá, Cali, Medellin) ○ Targets low-income families with informal land tenure • **Tropical Forest Community Mapping Initiative:** ○ Communities mapped in Cameroon, Central African Republic, Congo, Democratic Republic of the Congo, Gabon, Ghana, Peru ○ Works directly with indigenous peoples and forest-dependent communities
Number of Titles/Certificates Issued (2)	• **Landmapp:** Over 2,000 land tenure documents processed/sold/delivered to smallholder farmers as of Feb 2017 • **Mobile Application to Secure Tenure:** 910 Certificates issued (Pilot I); 1,126 Certificates issued (Pilot II)	• **Landmapp:** ○ Currently implemented in Ghana ○ Targets rural, smallholder farmers • **Mobile Application to Secure Tenure:** ○ Piloted in Burkina Faso, Tanzania ○ App is highly adaptable to facilitate replicability ○ Plans to scale to other West African and SE Asian countries
Efficiencies Achieved (4)	• **Aumentum Registry**: Land registration time down to an average of 2-7 days from 3 weeks • **Geodata Cadastral Database:** Survey errors from between 30-50 meters to below 1 meter • **Land Registration as a Solution:** Estimated to save $52 million over five years with digitized land registry • **Landmapp:** Cost of document processing is 60% of previous options	• **Aumentum Registry:** ○ Currently implemented in the Americas, Asia Pacific, North Africa, Middle East, and SSA ○ Used by governments • **Geodata Cadastral Database:** ○ Implemented in Australia, Philippines, USA, Vietnam ○ Used by governments • **Land Registration as a Solution:**

		○ Currently implemented in Western Australia • **Landmapp:** ○ Currently implemented in Ghana ○ Targets rural, smallholder farmers ○ Plans to scale to other West African and SE Asian countries

Note: Categories are not mutually exclusive

Two other technologies reported alternative measures of impact. The Land Matrix, a global online land monitoring initiative that aims to promote transparency and accountability in decisions over large-scale investments in land, has published 1,066 land transactions amounting to over 70.2 million hectares of land. Accessible through an online database, published transactions contain information on the purchaser, the location and size of the land transacted, intended purpose (e.g., agriculture or forestry), and contract status (e.g., completed or failed). Though Land Matrix is a global database, the majority of its published information on land investments are from Africa (422), followed by Asia (305), and finally by Latin America (146).

Red Tierras, a land rights program under that aims to help resolve disputes over contested land, has developed an app for mapping and registering primarily indigenous properties with evidence of implementation in Bolivia, Colombia, and Guatemala. By working with various stakeholders including land rights practitioners, indigenous communities, and government agencies, Red Tierras works to secure land rights for indigenous groups, facilitated through the creation of mediation centers for resolving land disputes. Red Tierras reports that, to date, they have resolved over 350 land disputes to the benefit of 115,000 indigenous families in Colombia and Guatemala. For their efforts, Red Tierras was one of three winning organizations selected from a total of 211 entries to be awarded an Ashoka Changemakers Award for 2011.

Implementation Challenges

Implementation challenges result from any difficulty faced by the organizations implementing the technology for one of the land tenure activity types. Of the 38 technologies reviewed, we find evidence of challenges with implementation for 16 technologies. Though detailed information on the majority of these instances was scarce, Table 9 summarizes initial findings and offers a brief description of the relevant information reported. Challenges are categorized as relating to Data Collection/Accuracy, and Project Complexity, and Other (types of challenges for which we found only one example and for which there were few details available).

Table 9. Implementation Challenges by Technology and Activity Type

Challenge	Type I: Enabling	Type II: Data Collection	Type III: Titling	Description
Data Collection/ Accuracy (6)	• Gender & Land Rights Database • Land Wise	• Geodata Cadastral Database • Global Forest Watch: Land Rights • Land Matrix • One Map Initiative	*n/a*	*Challenges in this category include inaccurately or incompletely collected data, inconsistent reporting, difficulties with digitizing aged documents, and inconsistently reported boundaries*

Project Complexity (2)	*n/a*	• Aumentum Cadastre • Talking Titler	• Aumentum Cadastre	*Challenges in this category stem from complexities in either land tenure arrangements or those due to historical and social dynamics*
Other (8)	• Land Use Planning for Tenure Security	• Mobile DHIS2 Tool • One Map Initiative • Red Tierras • SOLA Open Tenure • SOLA Systematic Registration • Suyo	• Mobile DHIS2 Tool • Red Tierras • SOLA Community Server • SOLA Registry • SOLA Systematic Registration • Suyo	*Challenges in this category include implementation difficulties related to training, language and communication, management, political related, and technological implementation*

Note: Categories are non-exclusive

Of the 16 land tenure technologies identified as experiencing implementation challenges we find evidence of data collection/accuracy challenges for organizations implementing six of the technologies reviewed. These challenges were due to various causes including: inaccurate data collected from dated survey records or difficulty in surveying due to terrain (Geodata Cadastral Database); non-standard data collection procedures across regions due to the use of different scales and non-uniform data reporting (One Map Initiative); non-reliable information attributed to crowd-sourcing of data (Land Matrix); incomplete or insufficient data collected as a result of non-uniform reporting standards or from a scarcity of resources (Gender and Land Rights Database, Landwise); and incomplete collection procedures based on prohibitive survey costs (Global Forest Watch).

As an illustration of one of these challenges, the Gender and Land Rights Database (GLRD), implemented and maintained by the FAO, faced challenges with reporting gender-related land tenure due to its inability to disaggregate data into meaningful information for recording land tenure. The GLRD found that some countries report land holdings at the holding level which could contain several plots, but that are typically reported with one holder per holding. Another reporting issue was that only holdings that met a particular value threshold would be reported leaving lower value holdings from being registered in national registries. In cases where women were more likely to manage or own holdings within either of these categories, their land tenure security would be underestimated (de la O Campos, Warring, & Brunelli, 2015).

In another example related to inaccurate data, the One Map Initiative, an initiative developed by USAID and the US Forest Service International Programs that aims to reconcile land tenure discrepancies and aggregate tenure data in Indonesia, faced difficulties documenting land boundaries because different ministries frequently maintained separate maps due to mistrust and opposing political affiliation. Out of a fear that the data would be misused, the ministries were reluctant to open their information and share it publicly with the One Map Initiative. This lack of cooperation meant that different ministries maintained maps with different and overlapping land boundaries (Shahab, 2016).

We find two instances of implementation challenges due to project complexity. In both cases the complexity stemmed from implementing registration databases in environments where historical and social arrangements

for defining land tenure were incompatible with proposed methods for registration— in other words integration would require an institutional overhaul.

In the case of Uganda, implementing the Aumentum Cadastre land tenure database was not immediately tenable due to the historical legal arrangement of land tenure systems. Land tenure in Uganda falls under four systems—Customary, Mailo/Native Freehold, Leasehold, Freehold—with all systems being recognized by the 1995 Constitution, but two of these being established under separate legal documents at different times. Customary land tenure is communally or jointly owned by groups of people through longstanding traditional or cultural institutions. The leasehold system is essentially contractual and define terms of access and usage. Finally, freehold land tenure refers to land tenure that develops its legitimacy from the Constitution and written law, such as a grant of land ownership in eternity (Ecoland, n.d.). Customary land tenure, which is approximately 80 percent of the land in Uganda and largely unregistered, is governed under the 1998 Land Act. Similarly, although land rights under the Mailo tenure system (a feudal land occupancy system located mostly in south-central Uganda) were established in the Uganda Agreement of 1900 (recognizing occupancy by tenants), tenant relationships with their landlords are now also governed by the provisions of the Land Act. Other land under the Leasehold and Freehold tenure systems is scattered throughout the country (Thomson Reuters, 2015).

In addition to these challenges, each tenure system maintained its own registry with registries being unable to communicate. The Mailo/Native Freehold and Customary tenure systems maintained decentralized registries while the Leasehold and Freehold registries were centralized making system unification challenging (Thomson Reuters, 2015).

In addition to these two categories of implementation challenges, we find evidence that participation in land tenure activities could be limited by language, technology skills, connectivity, and/or lack of cohesion among stakeholders (USAID, 2017; Global Forest Watch, 2014; Ashoka Changemakers, n.d.). The work of Red Tierras, for example, is predominantly centered on building consensus among different groups, including indigenous groups. Red Tierras attempts to address disputes and communication barriers by 1) providing a customized networking technology to facilitate communication; 2) translating their website into local languages; 3) training groups on computer/internet; and 4) tailoring land tenure workshops to education, cultural background, and technical expertise levels (Ashoka Changemakers, n.d.).

Synthesis of Findings

Securing land tenure has the potential to lead to a greater sense of ownership over land, greater equity in land access and land rights, increased land productivity, and greater access to financial opportunities for landholders (Deininger & Jun, 2006; Deininger, Ali, & Alemu, 2011; Ali, Deininger, & Goldstein, 2014; Lawry et al., 2017). Technology developers have come up with innovative mechanisms to help address land tenure in three activity types that we define as Type I (land tenure enabling) activities, Type II (land tenure data collection and aggregation) activities, and Type III (land titling) activities. We reviewed 38 different technologies and how they are used in each activity type, which technology platforms are required, data sources and dissemination, geographies served, populations served, costs and revenues, impact, and implementation challenges.

All of the technologies we identified work with desktop or laptop computers, and all rely on an internet connection at some stage. While Type I (enabling) activities (eight technologies) are accessed exclusively using internet connection through computers or mobile devices, Type II (data collection) activities show a more differentiated use of technology platforms. Twenty-six out of 26 data collection technologies use desktop or laptop computers, while 14 technologies use smart mobile devices, and two technologies use feature mobile devices. Complementary technologies include satellites (eight technologies), handheld GPS (three

technologies), drone/UAV (one technology), and others (three technologies). Moreover for Type II data collection activities, 18 out of 26 technologies identified use multiple technology platforms. Lastly, for Type III (land titling) activities, smart mobile devices (four technologies) and feature mobile devices (three technologies), are not used as often as desktop or laptop computer platforms (13 technologies). Only three technologies that participate in Type III activities use multiple technology platforms.

In terms of data use, we find that host organizations use a mix of original data collected through the technologies and data collected by other organizations. For Type I activities, there is a mix of technologies that use their own data, data collected by other organizations, or both and about half of those (9 out of 19) that collect data openly share the data and about half that use data from other organizations (7 out of 13) are using publicly available sources. For Type II activities, half of the technologies that specify their data source (6 out of 12) collect original data, and the other half use both original data and data from other organizations, and none of the technologies reported that the data collected and used are openly shared or publicly available.

In terms of implementation, the technologies we reviewed for Type I activities work primarily in Sub-Saharan Africa and Southeast Asia. Geographies served by technologies that address Type II activities are more diversified, ranging from Latin America to Africa, Asia, Oceania, and North America. Type III activities also serve a range of geographies around the globe. Twenty-seven of the technologies reviewed specify a target population: the most targeted populations are low-income and rural populations (nine technologies each), followed by women (eight technologies), and indigenous groups (seven technologies).

While not much cost and revenue information was available, 15 technologies mention some sort of fee for clients to use the technology. Other types of costs include administrative costs, technology creation costs, one-time access fees, subscription costs, and land title registration costs. To date there appears to be very limited information available to evaluate the costs associated with land tenure technologies individually or in aggregate.

Our review of the impacts of technologies – including any impact measures that the technology websites mentioned – revealed 16 technologies for which some sort of impact measure has been reported, most commonly including the number of parcels mapped and digitized, the number of titles/certificates issued, and efficiencies achieved in land administration systems.

Finally, 16 technologies report some sort of implementation challenge. Data collection/accuracy and project complexity were the most commonly mentioned challenges with six technologies and two technologies, respectively. Other challenges include training, language and communication, management, geopolitical issues, and technological implementation.

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Appendix A - Summary of Search Results

Search String	Source	Unique Results Identified and Coded
land rights and land tenure technologies	Google	21
("land rights" OR "land tenure") AND (technology OR software OR program OR platform) AND (map OR records OR mapping OR digital OR digitize)	Google	14
Africa AND ("land rights" OR "land tenure") AND (technology OR software OR program OR platform) AND (map OR records OR mapping OR digital OR digitize)	Google	1
("Latin America" OR "South America") AND ("land rights" OR "land tenure") AND (technology OR software OR program OR platform) AND (map OR records OR mapping OR digital OR digitize)	Google	1
Asia AND ("land rights" OR "land tenure") AND (technology OR software OR program OR platform) AND (map OR records OR mapping OR digital OR digitize)	Google	1

Appendix B – Multi-Purpose Technologies

Technology Name	Brief Description	Case Study Example
3D GIS in the Cloud (3D GIS Cadastral GIS) http://sivandesign.com/products/3dgis/	3D-GIS in the Cloud is a cadaster and urban planning tool that aims to evaluate and assist in designing the use-efficiency of both existing and planned spatial areas. The application provides a realistic and detailed 3D model of parcels, features, and structures, as well as ownership information. 3D-GIS in the Cloud can be used to perform impact analyses of structures and parcels, or query a feature of area for contextual GIS information. Processes include: simulate proposed plans and test different scenarios; analyze data and impacts not achievable in a 2D environment; time-of-day visualization and analysis of a structures volumetric shadow affect; visualize proposed changes in the city skyline and evaluate impacts; evaluate area/line-of-sight from various observation points and heights; create realistic 3D flythrough animations of any scenario such as touring within a proposed project of evaluating situational impacts; and evaluate expropriation of underground sub-parcels.	Land Survey of Israel: http://sivandesign.com/company/global-projects/3d-cadastre-gis/
Blockchain Property Rights Registry http://bitfury.com/products#software-offerings	This cutting-edge project uses blockchain technology and distributed timestamping services to build audit infrastructure on top of existing public registries for property rights registration. A private blockchain used for this purpose (and secured with the public Blockchain) could mitigate the possibility of corruption while also providing clients with secure and verifiable electronic receipts. This project allows for independent audits of smart contracts as well as decentralized identity management. It also has the potential to streamline the entire public registry process and allow for ongoing maintenance through digital channels.	Title Registration in Georgia: The Republic of Georgia has partnered with The Bitfury Group to advance transparency by developing a system for registering land titles using the Blockchain for the National Agency of Public Registry. Hernando de Soto, The Bitfury Group board advisor and economist known for his work on the importance of property rights, will assist with platform development. This pilot project is the first of many property rights registry projects to come.https://www.forbes.com/sites/laurashin/2017/02/07/the-first-government-to-secure-land-titles-on-the-bitcoin-blockchain-expands-project/#2785cb514dcd
CyberTracker https://www.cybertracker.org/	Originally developed to enable trackers to monitor animal behavior in game parks, the CyberTracker system has been adapted for land titling purposes, so that community members can use it to gather spatially referenced data to complement or update their video testimonies. Community members are asked to provide socio-economic data, such as marital status, family size, etc., using a handheld computer with an icon-based touch-screen interface. The system is easy to use in the field, even by non-literate users.	Establishing tenure for informal settlements in Cape Town, South Africa: https://www.cybertracker.org/downloads/social/Data_Collection.pdf
Emlid ReachRS https://emlid.com/reachrs/	Emlid Reach RS is a technology developed to survey, map, and collect land boundary data. The technology is equipped with a high performance dual-feed antenna that connects with GPS, OLONASS, BeiDou, Galileo, QZSS, and SBAS satellites.	Landmapp smallholder mapping in Ghana: http://www.landmapp.net/
Geosystems UAV http://leica-geosystems.com/en-us/products/airborne-systems/uav	Geosystem's Leica Aibot X6 UAV has been designed to collect precision data for aerial mapping, inspection, agriculture, and forestry applications, and creates highly detailed and accurate images and videos.	Mapping in Peru through the Land Alliance project "Drones for Land Rights": http://thelandalliance.org/wp-content/uploads/2015/11/UAV-based-participatory-electronic-formalization-Concept-Paper-modified-for-use-on-Land-Alliance-Website-copy.pdf
Land Administration: Airbus Defense and Space, Inc. http://www.intelligence-airbusds.com/en/8	"Increasingly today, computerised and web-enabled information systems allow maximum access to cadastral mapping and property registers for use by governments, property owners and professional groups. They do satellites. We pride ourselves in our ability to cover the complete spectrum of services from data acquisition (both aerial and satellite) and data capture from existing records, through data processing, formatting and analysis to data management, hosting, serving and visualisation. These processes often use systems and software that we and our key partners have designed, developed and	Mauritius Land Registration: http://www.intelligence-airbusds.com/en/176-mauritius-case-study

9-land-administration	installed." Airbus Defense and Space assists governments and major donor agencies in land administration project definition, implementation, and evaluation. They have guided several countries in land administration expertise to support their transition to a market economy and have supported others in the implementation of various cadastre and land registration projects. There are examples of such projects on their website from Mauritius, the UK, Slovenia, Ireland, Vietnam, and Nigeria. Source information found at: http://www.intelligence-airbusds.com/en/89-land-administration.	
OpenStreetMap https://www.openstreetmap.org	OpenStreetMap (OSM) aims to create a community model for collaborative, open geographic data creation and sharing for adaptation to the particular access rules and data structures required for land tenure registration. This is accomplished by the creation of an open source mapping software which allows users to view and edit an open digital map of their own community.	Kibera, Kenya Community Mapping Project: http://mapkibera.org/
Pix4Dmapper Pro https://pix4d.com/	Software used to create maps from drone-produced images.	Namibia Mapping Project: https://pix4d.com/drawing-boundaries-with-uav-mapping-customary-lands-in-namibia/
Radiant http://radiant.earth/	Radiant's geospatial technology platform will permit users to illuminate earth, literally, to allow everywhere to be "seen"; to turn the telescopes back on human activity as we enter the Anthropocene period; and to give decision-makers a scientific window into understanding global activity better. Providing the global community with these tools and data can create powerful insights and accelerate greater catalytic, evidence-based support for change.	No current projects specified
Ushahidi https://www.ushahidi.com/	Crowd sourced data collection application (smart phone) that allows people to create custom surveys to collect the "pulse" from negative situations (natural disasters is the main use, but the website specifically talks about mapping how companies may encroach on indigenous land and forests). Although Ushahidi serves as a model for what has been coined as 'activist mapping' and is extensively used to support disaster management and recovery, it is also beginning to be used to crowdsource information about land incidents, including land acquisitions. Good examples are 'Let's Talk Land Tanzania', the gateway to land related Information in Tanzania, where citizens can submit reports on land incidents and identify their locations on a map, and Deriban.net which allows civic activists and ordinary citizens to submit reports on land violations in Ukraine.	Let's Talk Tanzania: https://indigotrust.org.uk/2012/10/29/mapping-land-grabbing-for-transparency-and-advocacy/
V-Map Precision Mapping with Drone http://www.microaerialprojects.com/v-map-system/	The V-Map technology is used to map land boundaries through the use of UAVs combined with photographic and GPS technology. The technology is accompanied with a GPS post processing software which documents the images and GPS data collected during the UAV mapping. This technology has been used to map land administration projects in Albania and Ghana.	Mapping projects in Albania and Ghana: http://www.microaerialprojects.com/services/international-development/
Wolf-GIS APEX http://www.wolfgisapex.com/.	Wolf GIS APEX is "a fully functioning mobile GIS app tool for a wide variety of uses." Uses include, but are not limited to, asset identification systems, land management and information, project documentation and compliance, and data gathering and collection. "Wolf-GIS APEX is GIS on the go. It has the ability to work in the field, at the desk, or on the road while storing your data on a server. Wolf-GIS has given the everyday person the ability to work in GIS." Information retrieved from http://www.wolfgisapex.com/.	No current projects specified

Appendix C – Technology Review Framework

Technology Introduction

- Technology/program name
    - Describe briefly

- Technology/program developer name
    - Host organization sector (academic, private – NGO/NPO, private – for profit, public)
- Partner organization (e.g., technology implementer, funder, etc.) names
    - Partner organization sector (academic, private – NGO/NPO, private – for profit, public)
    - Describe services provided by/role of partner organizations
- Technology website
    - Additional sources
- Year created
    - Ongoing or year ended

Type I: Technology Description and Implementation

- Does this organization operate in Type I – enabling activities (y/n)
- Is technology used for Type I activities (y/n)
- Describe goal and intended outcomes related to Type I activities
- Technology platforms used by host organization
    - Does the host organization use a computer – desktop platform (1=y; 0=n)
    - Does the host organization use a mobile device – smart platform (1=y; 0=n)
    - Does the host organization use a mobile device – feature platform (1=y; 0=n)
    - Does the host organization use satellite GPS/imagery (1=y; 0=n)
    - Does the host organization use handheld GPS (1=y; 0=n)
    - Does the host organization use drone/UAV (1=y; 0=n)
    - Does the host organization use other technology (1=y; 0=n)
    - Does the host organization require internet to operate the technology? (1=y; 0=n)
- Describe the technology's role and delivery/implementation process (e.g., registration, data collection, management, etc.)
- Describe speed of delivery and length/frequency of interaction
- Technology platforms used by client/targeted landholder
    - Does the client/targeted landholder use a computer – desktop platform (1=y; 0=n)
    - Does the client/targeted landholder use a mobile device – smart platform (1=y; 0=n)
    - Does the client/targeted landholder use a mobile device – feature platform (1=y; 0=n)
    - Does the client/targeted landholder use satellite GPS/imagery (1=y; 0=n)
    - Does the client/targeted landholder use handheld GPS (1=y; 0=n)
    - Does the client/targeted landholder use drone/UAV (1=y; 0=n)
    - Does the client/targeted landholder use other technology (1=y; 0=n)
    - Does the client/targeted landholder require internet to operate the technology? (1=y; 0=n)
- Describe technology's role and how the client/targeted landholders interact with technology (e.g., length and frequency of interaction, transparency of implementation, etc.)
- Does the targeted landholder need to provide their own form of this technology, or is it provided by the organization?
    - Describe
- Does the organization collect original data, use data collected by other organizations, or both for Type I activities (original/other organizations/both)
    - If the organization collects data, how
    - Is this collected data then openly shared (y/n)
        - Describe
    - If the organizations uses data collected by other organizations, are data sources publicly available (y/n)
        - Describe data sources
    - Does the organization publicly distribute data related to Type I activities (y/n)
        - Describe

Type II: Technology Description and Implementation

- Does this organization operate in Type II – data collection activities (y/n)
- Is technology used for Type I activities (y/n)
- Describe goal and intended outcomes related to Type II activities
- Technology platforms used by host organization
    - Does the host organization use a computer – desktop platform (1=y; 0=n)
    - Does the host organization use a mobile device – smart platform (1=y; 0=n)
    - Does the host organization use a mobile device – feature platform (1=y; 0=n)
    - Does the host organization use satellite GPS/imagery (1=y; 0=n)
    - Does the host organization use handheld GPS (1=y; 0=n)
    - Does the host organization use drone/UAV (1=y; 0=n)
    - Does the host organization use other technology (1=y; 0=n)
    - Does the host organization require internet to operate the technology? (1=y; 0=n)
- Describe the technology's role and delivery/implementation process (e.g., registration, data collection, management, etc.)
- Describe speed of delivery and length/frequency of interaction
- Technology platforms used by client/targeted landholder
    - Does the client/targeted landholder use a computer – desktop platform (1=y; 0=n)
    - Does the client/targeted landholder use a mobile device – smart platform (1=y; 0=n)
    - Does the client/targeted landholder use a mobile device – feature platform (1=y; 0=n)
    - Does the client/targeted landholder use satellite GPS/imagery (1=y; 0=n)
    - Does the client/targeted landholder use handheld GPS (1=y; 0=n)
    - Does the client/targeted landholder use drone/UAV (1=y; 0=n)
    - Does the client/targeted landholder use other technology (1=y; 0=n)
    - Does the client/targeted landholder require internet to operate the technology? (1=y; 0=n)
- Describe technology's role and how the client/targeted landholders interact with technology (e.g., length and frequency of interaction, transparency of implementation, etc.)
- Does the targeted landholder need to provide their own form of this technology, or is it provided by the organization?
    - Describe
- Does the organization collect original data, use data collected by other organizations, or both for Type II activities (original/other organizations/both)
    - If the organization collects data, how
    - Is this collected data then openly shared (y/n)
        - Describe
    - If the organizations uses data collected by other organizations, are data sources publicly available (y/n)
        - Describe data sources
    - Does the organization publicly distribute data related to Type II activities (y/n)
        - Describe

Type III: Technology Description and Implementation

- Does this organization operate in Type III – titling activities (y/n)
- Is technology used for Type III activities (y/n)
- Describe goal and intended outcomes related to Type III activities
- Technology platforms used by host organization
    - Does the host organization use a computer – desktop platform (1=y; 0=n)
    - Does the host organization use a mobile device – smart platform (1=y; 0=n)
    - Does the host organization use a mobile device – feature platform (1=y; 0=n)
    - Does the host organization use satellite GPS/imagery (1=y; 0=n)
    - Does the host organization use handheld GPS (1=y; 0=n)
    - Does the host organization use drone/UAV (1=y; 0=n)
    - Does the host organization use other technology (1=y; 0=n)

    - Does the host organization require internet to operate the technology? (1=y; 0=n)
- Describe the technology's role and delivery/implementation process (e.g., registration, data collection, management, etc.)
- Describe speed of delivery and length/frequency of interaction
- Technology platforms used by client/targeted landholder
    - Does the client/targeted landholder use a computer – desktop platform (1=y; 0=n)
    - Does the client/targeted landholder use a mobile device – smart platform (1=y; 0=n)
    - Does the client/targeted landholder use a mobile device – feature platform (1=y; 0=n)
    - Does the client/targeted landholder use satellite GPS/imagery (1=y; 0=n)
    - Does the client/targeted landholder use handheld GPS (1=y; 0=n)
    - Does the client/targeted landholder use drone/UAV (1=y; 0=n)
    - Does the client/targeted landholder use other technology (1=y; 0=n)
    - Does the client/targeted landholder require internet to operate the technology? (1=y; 0=n)
- Describe technology's role and how the client/targeted landholders interact with technology (e.g., length and frequency of interaction, transparency of implementation, etc.)
- Does the targeted landholder need to provide their own form of this technology, or is it provided by the organization?
    - Describe
- Does the organization collect original data, use data collected by other organizations, or both for Type III activities (original/other organizations/both)
    - If the organization collects data, how
    - Is this collected data then openly shared (y/n)
        - Describe
    - If the organizations uses data collected by other organizations, are data sources publicly available (y/n)
        - Describe data sources
    - Does the organization publicly distribute data related to Type III activities (y/n)
        - Describe

Overview Information

- Is this technology an online map/database tool (y/n)
    - Describe
- Does this technology require in-person interactions between the host organization and the client/targeted landholder (y/n)
    - Describe
- Transparency/openness of implementation and management (high/med/low)
    - Describe
- Does the technology work with other technologies (y/n)
    - Name of other technologies
    - Describe role of other technologies and types of activities they are used with
- Any evidence for dispute resolution (y/n)
    - Describe
- Organizations responsible for implementation and management
    - Describe administrative responsibilities of responsible organizations
- Any evidence of implementation, management, or other technology-related challenges (y/n)
    - Type of challenge (funding/costs; interpersonal/political conflict; length of time; lack of non-funding resources; unable to collect accurate/complete data; language/communication; lack of transparency; lack of training/education; complex scope; not specified)
    - Describe

Costs and Revenues

- Are the costs to create the technology mentioned (y/n)
    - Describe
- Are the costs to maintain the technology mentioned (y/n)

    - Describe
- Are the costs to implement and administer/manage the technology mentioned (y/n)
    - Describe
- Are there costs to the client (y/n)
    - Describe
- Are revenue streams mentioned (y/n)
    - Describe
- Are funders mentioned (y/n)
    - Describe
- Are any challenges related to costs mentioned (y/n)
    - Type of challenge
    - Describe
- Other cost, revenue, and funding information

Market and Scale

- Is the technology currently being implemented in target geographies (y/n)
- Is the target geography global (y/n); if no, specify which regions
    - Is Northern Africa included in the target geographies (y/n)
    - Is Sub-Saharan Africa included in the target geographies (y/n)
    - Is Latin America and the Caribbean included in the target geographies (y/n)
    - Is Northern America included in the target geographies (y/n)
    - Is Central Asia included in the target geographies (y/n)
    - Is Eastern Asia included in the target geographies (y/n)
    - Is South-eastern Asia included in the target geographies (y/n)
    - Is Southern Asia included in the target geographies (y/n)
    - Is Western Asia included in the target geographies (y/n)
    - Is Europe included in the target geographies (y/n)
    - Is Australia and New Zealand included in the target geographies (y/n)
    - Is other Oceania included in the target geographies (y/n)
    - Specify geographies where technology is being implemented
        - Describe (i.e. list projects and web links that have occurred in these geographies)
- Are targeted landholders mentioned (y/n)
    - Describe
- Does the technology specifically target women (y/n)
    - Describe
- Does the technology specifically target other vulnerable populations (y/n)
    - Describe
- Does the technology mention clients (separate from targeted landholders) (y/n)
    - Describe
- Is there any evidence of challenges related to inclusiveness or equity of the technology (especially for women, smallholders, or other vulnerable populations) (y/n)
    - Describe
- Does the technology mention future plans (changes to scale, changes to technology, new partnerships, etc.) (y/n)
    - Describe
- Does the technology mention replicability (y/n)
    - Describe
- Any evidence of challenges related to scalability or replicability (y/n)
    - Describe

Impacts/Benefits

- Are there any formal evaluations of the implementation and impacts of the technology (y/n)
    - Describe
- Is there any other evidence regarding the achieved impact or benefits of the technology (y/n)
    - Describe
- Primary measure of impact/benefit
    - Estimate of impact/benefit
- Secondary measure of impact/benefit
    - Estimate of impact/benefit

Appendix D – Description of all Identified Land Tenure Technologies

Technology/Program Name	Describe briefly
Aumentum Cadastre (https://tax.thomsonreuters.com/aumentum/)	Aumentum Cadastre integrates survey and cadastral management tools that allow the client to collect and manage geographic cadastre property data and make that data accessible to the public. The technology uses ArcGIS as a base, and improves efficiencies in terms of processing time and cost. Aumentum Cadastre enables clients to create and maintain integrated geographic data by collecting property data, generating maps, and providing data access to the public. Cadastre integrates with other softwares in the Aumentum suite (excluding OpenTitle), including Aumentum Registry, to assist clients in all phases of the property registration process.
Aumentum OpenTitle (https://tax.thomsonreuters.com/aumentum/)	Aumentum OpenTitle is an easy-to-use and inexpensive tool for rural communities to map their land in order to gain property rights. It streamlines the collection process through the use of built-in GPS, aerial imagery, and other data sources, and provides custom support and advice. It is meant for small governments or governmental partners who don't have the budget to build custom land registry platforms or do not have the technical knowledge to do so. OpenTitle is a stand-alone, all-in-one product that integrates document management with mapping capabilities. "OpenTitle offers an entry-level solution for small registry office environments based on pro-poor land rights standards." (https://tax.thomsonreuters.com/wp-content/pdf/aumentum/1004045_Aumentum%20Corporate%20INT_(web).pdf)
Aumentum Registry (https://tax.thomsonreuters.com/aumentum/registry/)	Aumentum Registry is an automated land information system that facilitates the registration of real estate and property-based transactions by digitizing and streamlining the registration system. It is systematic and transparent, and is thus intended to circumvent property disputes or tampering with data. The software helps streamline administrative land transactions after there is a consistent system for documenting land rights already in place, helps to automate processes to reduce bottlenecks and wait times, and stores data/information securely. Registry integrates with other softwares in the Aumentum suite (excluding OpenTitle), including Aumentum Cadastre, to assist clients in all phases of the property registration process.
Cadasta Platform (http://cadasta.org/platform/)	Cadasta provides a platform for the digitization of land records, using simple, affordable tools. These tools can be used to help partners efficiently document, analyze, store, and share critical land and resource rights information. Includes an optional plugin for QGIS, and also employs ODK and GeoODK for off-line mapping and data collection. Information from ODK and GeoODK can be imported directly into the Cadasta platform.
Focus on Land in Africa (FOLA) (http://www.focusonland.com/countries/explore-by-country/)	Focus on Land in Africa (FOLA) is an educational resource for development practitioners and policy makers that explores how land and natural resource rights affect, and are effected by, development in Africa. Through raising awareness of these issues, FOLA aims to elevate land and natural resource rights as an urgent priority for development in Africa. While never offering a blueprint, FOLA shares a diversity of insights, experiences, and lessons from countries across the continent, highlighting the critical role of property rights in local livelihoods and development. It examines the impact of land and natural resource rights on agriculture, the environment, conflict, urban poverty, women's empowerment, and other development issues. It provides in-depth analysis of a variety of property rights issues, and how they are addressed in different countries and contexts.
Gender and Land Rights Database (http://www.fao.org/gender-landrights-database/data-map/statistics/en/)	The GLRD was launched by FAO in 2010 to provide policy makers, legislators and advocates of women's land rights, with up-to-date country level information on the legal developments and factors that promote or prevent the realisation of gender-equitable land tenure. The GLRD serves as a platform to share information on gender and land tenure with the support of 84 country profiles, sex-disaggregated data on land, and a Legal Assessment Tool (LAT) for gender-equitable land tenure. The database has a tool for assessing the extent to which national legal frameworks enable gender-equitable land tenure, assessing 30 legal indicators in different countries.
Geodata Cadastral Database (https://www.geodata.com.au/)	Geodata Australia provides skills and technologies in survey and GIS cadastral database management to properly demarcate and document property for governments and industry. This is accomplished through using GPS technology to map boundary data which is then recorded in a standard SQL database via the GeoCadastre and GeoSurvey applications.

Global Forest Watch: Land Rights (http://www.globalforestwatch.org/map/3/15.00/27.00/ALL/grayscale/loss,forestgain/602?tab=analysis-tab&begin=2001-01-01&end=2016-01-01&threshold=30&dont_analyze=true)	Global Forest Watch is working collaboratively with other groups to visualize land tenure data under the "People" tab of their interactive online system. Users are able to overlay tenure information with forest change and other forest use data for many countries. These data will help users understand the effectiveness of communities in protecting forests, and identify areas with unclear land allocations and tenure. "Land Rights" refers to areas over which indigenous peoples or local communities enjoy rights to the land and certain resources, whether legally recognized or not. The exact nature of these land rights varies among tenure type and country. The land rights data on GFW, while displayed as a single layer, is assembled on a country-by-country basis from multiple sources.
Innola Solutions (http://innola-solutions.com/)	Innola Solutions aims to build innovative land administration platforms for clients – which includes land administration stakeholders, such as decision makers, business and administrative managers, clerks, customers, IT system administrators, and analysts – by providing an optimal balance between system functionality, ease of use, configurability and customization. This is accomplished by creating a fully web-based professional open software framework for registering, managing, and distributing property objects and related data.
its4land (https://its4land.com/)	Its4land aims to deliver a set of land tenure recording tools that respond to Sub-Saharan Africa's immense challenge to rapidly and cheaply map millions of unrecognized land rights in the region. The objective of its4land is to offer an innovative suite of land tenure recording tools inspired by geo-information technologies, that responds to end-user needs and market opportunities in Sub-Saharan Africa, reinforcing an existing strategic collaboration between EU and East Africa. It accomplishes this by combining emerging geospatial technologies including smart sketchmaps, UAVs, automated feature extraction, and geocloud services that are cheap, fast, easy, and responsible in an end-user responsive and market-driven way.
Land Matrix (http://www.landmatrix.org/en/)	The Land Matrix is a global and independent land monitoring initiative that aims to promote transparency and accountability in decisions over land and investment. The Land Matrix is a global project which maintains a database of large-scale land acquisitions around the world. Land tenure security can indirectly be strengthened by the Land Matrix's process of identifying and making transparent large-scale land acquisitions, particularly those deals that affect smallholder farmers and other vulnerable populations.
Land Portal (http://landportal.info/)	The leading online resource for information, data and knowledge-exchange on land governance issues. By increasing access to information on land, Land Portal aims to ensure responsible land governance and secure land rights for the world's poor and vulnerable. The Land Portal collects, organizes, and disseminates a broad range of land-related data and information that is otherwise fragemented and inaccessible. The development of Land Portal is an ongoing, collaborative effort, involving global and local partnerships as well as contributions from a diverse range of research organizations, civil societies, governments, academia, independent researchers, land rights activists, and other stakeholders.
Land Registration as a Solution (LRaaS) (https://advara.com/)	The Land Registration as a Solution (LRaaS) technology aims to increase the efficiency and cost-effectiveness of land title registration services by changing paper-based documentation to digital-based. This is accomplished by implementing a cloud-based database that interacts with legacy land registry systems allowing users to organize and store documentation for properties in a virtual database.
Land Resource Manager (http://www.trimble.com/Forestry/Land-Forest-Management.aspx?tab=Land_Admin)	Land Resource Manager (LRM) is an intuitive and easy-to-use enterprise application for managing tabular and spatial information within the land and forest business. LRM identifies which actions need to happen on which locations, optimizes activity scheduling, budgeting and resource allocation, determines priorities, tracks progress and provides a thorough perspective on activities and costs for critical decision support, resource planning, compliance and stakeholder reporting. Land Records: Tracks all associated land rights, leases, adjacencies, encumbrances, subdivisions, lots and tax parcels. The data is integrated with the spatial representation and relationships are created automatically based on the spatial location of each item. As properties are split or merged, bought or sold, the system archives all related spatial and attribute history.
Land Rights Platform (http://sithi.org/temp.php?url=landrights%2Flandrights.php&lg=)	The Cambodian Center for Human Rights (CCHR) developed an online interactive content on land rights education to incorporate into the popular Cambodian Human Rights Portal sithi.org. The project aims to increase knowledge among urban youth about key issues surrounding land rights in Cambodia, based on the assumption that more accessible materials could improve awareness. CCHR created Cambodia-specific videos, infographics, quizzes, and supporting documents on five topics to raise awareness about land right issues such as land ownership, acquisition of ownership, procedures on access to land titles, land concessions, and land dispute resolution mechanisms.

Land Use Planning for Tenure Security (http://gltn.net/index.php/publications/publications/publications-list/send/2-gltn-documents/2199-land-use-planning-for-tenure-security-a-brief-eng-2015)	GLTN aims to develop a pro-poor land-use planning tool with a particular focus on both rural and urban environments in developing countries. The two main objectives of the tool are to: Building from GIZ's Manual on Land Use Planning (LUP) as a starting point, develop a robust land use planning tool with special focus on land tenure security and applications in developing countries; and develop a training package from the enhanced land use planning tool. The e-learning package is useful for independent e-learning by students or trainees, as well as serving as a training tool for lecturers or trainers in capacity development involving LUP for tenure security initiatives. This tool has yet to be developed.
Landfolio Software (http://landadmin.trimble.com/solutions/land-management/)	Landfolio software is a leading land management software suite that automates and integrates all key elements of land administration management. Built on the ESRI® platform and other industry leading databases, this completely configurable software suite is easily localized and integrates your key land management workflows — from registry and cadastre to natural resources management. Landfolio provides a unified and standardized project management workflow throughout the parcel subdivision process. User friendly "Parcel Wizards" guide the inexperienced user through parcel management activities that include splitting, amalgamating, subdividing, creating and adjusting parcel boundaries.
Landmapp Project (http://www.landmapp.net/)	The Landmapp Project is a mobile application that provides mapping and registration technology to smallholder farms. Landmapp uses cutting edge mobile GPS and GNSS technology to map property, and collects and manages all this data via the app. The data can either be stored or uploaded to the cloud, and then Landmapp staff use the smallholder maps and information to obtain land certification titles for the farmers.
LandMark (http://www.landmarkmap.org/)	LandMark was designed to help Indigenous Peoples and communities protect their land rights and secure tenure over their lands. This is accomplished through the creation of an online, interactive global platform that provides maps and other critical information on lands collectively held and used by Indigenous Peoples and local communities. LandMark is an open source software allowing anyone interested in indigenous/customary land status to access various information including documentation status (formally recognized by government or not) and boundaries around the globe.
Landwise (http://landwise.resourceequity.org/about)	LandWise is a free online resource connecting users to legal materials, information about relevant customary practices, and explanatory materials. LandWise empowers policymakers, researchers, legal practitioners, and women's advocates to strengthen women's land rights. LandWise aims to empower users to strengthen women's land rights around the world through access to relevant and reliable information by providing access to land laws, family laws, and related material from as many countries as possible.
MAST: Mobile Application to Secure Tenure (https://www.land-links.org/project/mobile-application-to-secure-tenure-tanzania/)	The Mobile Application to Secure Tenure (MAST) is a pilot project that supports the improvement of land governance and lower the cost of land certification programs. MAST is an open-source smartphone application that aims to strengthen land tenure in underdeveloped rural areas by mapping property boundaries and documenting ownership status in Tanzania.
mLocGov (http://www.manobi.net/?IDPage=5&M=3)	Decentralization in most of the countries of the South is leading to an increase in the responsibilities of local governments that lack the solutions to carry out these responsibilities effectively. MLocGov is the platform dedicated to local authorities to improve their management and strengthen their capacity to deliver their basic services to their citizens. It integrates solutions for land management, inventory and management of commercial and non-market assets, development of local development plans, succession and collection of taxes and royalties, and interaction solutions and services And communication with citizens.
Mobile DHIS2 Tool (http://akros.com/informatics/land-tenure/)	Akros designed and deployed a mobile DHIS2 tool for rural Zambians to track changes in their land claims. These data changes are immediately sent to the Chipata District Land Alliance's (CDLA) central repository, allowing the local chief to print and deliver customary land certificates.
Mobineo (https://www.f6s.com/mobineo)	Not a lot of information available online, but was founded with the goal of digitizing land surveying in the developing world. Mobineo is seeking to resolve this by creating an Android application and GPS device that will allow government land surveyors to accurately document ownership claims.
One Map Initiative (https://sig-gis.com/projects/one-map-indonesia/)	Indonesian database developed by USAID and US Forest Service International Programs that brings together land tenure, land use, and other spatial data to reconcile discrepancies and aggregate data in one location. Also includes a participatory mapping aspect that allows users to create layers of interest, which are later verified and incorporated into national datasets that can be accessed by others.

Open Development Initiative (https://opendevelopmentcambodia.net/)	Open Development Initiative (ODI) is an 'open data' website. ODI does not promote any particular perspective, agenda or bias other than to provide objective information about each country and its development. As an online hub compiling freely available data in a 'one-stop shop', ODI provides the public with up-to-date, accurate information about each country and its economic and social development. Its open data approach guarantees materials and information are available to all users for use and download. ODI hopes that the site and the data will facilitate research and communication between the public, private companies, civil society and governments. Each ODI country has a map and information on country-specific land rights issues, and some cover a variety of other environmental, economic, and social areas as well.
RAISG (https://www.amazoniasocioambiental.org/)	Database of knowledge (produced and collected by the RAISG collective), statistical data and geospatial socio-environmental information on the Amazonia region. Includes maps, data and statistics related to land use, indigenous land rights, etc. Intended to facilitate better understanding and study of Amazonia as a broader region, rather than as fragmented countries.
Red Tierras (https://www.mercycorps.org/tags/red-tierras)	Red Tierras began as a program intended to solve land disputes through mediation in Guatemala, Bolivia, and Colombia. As the program expanded, Red Tierras developed a mobile application that facilitates and expedites the registration process for formalizing property rights. They use a variety of technologies - mobile (SMS), aerial imagery, GPS - to facilitate community-based land registration. The technology is a customized version of OpenTitle from Thomson Reuter, in concert with ThoughtWorks.
Sarawak Geoportal (http://www.bmfmaps.ch/EN/composer/#maps/1001)	Interactive mapping portal for the island of Sarawak. It is intended to be used to provide information to indigenous Sarawak residents, who could then protect their native and customary land by employing this data.
Sistema de información sobre comunidades nativas de la amazonía peruana (SICNA) (http://www.ibcperu.org/mapas/sicna/)	SICNA is a georeferenced database containing geographic and tabular information on native communities. The use and dissemination of this information promotes the defense of indigenous peoples' rights, encouraging the titling of native communities and the protection of indigenous peoples. SICNA collects information through surveys and GPS, and then shares information and maps through the online databased in the hopes that this information will aid in the titling of native communities and the creation of territorial reserves, as well as in the defense and management of indigenous territories. Additionally, SICNA hopes that this work will contribute to the creation of an official cadastre of native communities, an important tool to avoid overlapping properties or concessions on native communities, and for the territorial ordering of the Peruvian Amazon.
Social Tenure Domain Model (http://stdm.gltn.net/)	The Social Tenure Domain Model (STDM) is a pro-poor, gender responsive and participatory land information system developed by the Global Land Tool Network (GLTN). STDM has been developed to bridge the gap between formally registered land and land that is not registered.
SOLA Community Server (http://flossola.org/index.php/solutions/community-server)	SOLA Community Server is an online database created by the FAO as part of their "Solutions for Open Land Administration" software suite. The software can be downloaded directly from the website for free, and is used by a designated "Community Recorder" to upload details regarding the community's land tenure. The details can then be reviewed, "community recognized" tenure rights can be published, and titles generated. Community Server is often used in concert with SOLA Open Tenure - data from Open Tenure can be uploaded directly from the app to the Community Server.
SOLA Open Tenure (http://flossola.org/index.php/solutions/open-tenure)	SOLA OpenTenure is a mobile-based application intended for use by young adults to map and collect data regarding community and individual land tenure. It integrates with SOLA's other software (Community Server), and information regarding community land tenure can be uploaded directly from the map to the Community Server, or can be used as a cache if wireless internet is not available while in use. It is available for free download from the SOLA website. The FAO promotes acceptance of the Voluntary Guidelines for Responsible Governance of Tenure (VGGT) and implementation of these guidelines are facilitated by the app. (Used with Community Server)
SOLA Registry (http://flossola.org/index.php/solutions/registry)	SOLA Registry is the first iteration of SOLA software, created by the FAO and funded by the Government of Finland for land administration agencies. SOLA registry software provides integrated registration and cadastral function, case management and a LADM compliant database for land administration agencies. The open source software is available via a free download and can be customized to suit the host country/agency's needs. SOLA is dedicated to implementing this open source computerized cadastre and registration system that is both affordable and sustainable to best serve developing countries. It integrates with other SOLA products - allowing data to upload via Open Tenure, and organized/stored through Registry. This data can also be uploaded to the Community Server.

SOLA Systematic Registration (http://www.flossola.org/index.php/solutions/systematic-registration)	SOLA Systematic Registration supports the registration of land with new tenure information by gathering and managing information, granting land titles, or organizing and transferring information to government agencies as needed. Different than other SOLA suite softwares, SOLA Systematic Registration aims to support activities where tenure information is being collected for the first time. SOLA Systematic Registration produces public display listings and maps, generates title certificates, and can transfer data to district or national land offices enabling centralized control and maintenance of tenure records. SOLA Systematic Registration focuses on supporting decentralized collection of tenure information through a coordinated systematic registration process.
Suyo (https://www.suyo.co/)	Suyo aims to provide affordable and reliable property formalization services to Latin American communities, in order to help low-income families unlock the social and economic benefits of property. Suyo is a "property data platform and mobile communications strategy for property formalization" that currently operates in Colombia. Suyo agents work with clients to target low-income families in informal settlements and complete the process of property formalization with them, from documenting information through the mobile app, to collecting content on the data platform and submitting an application to proper authorities.
Talking Titler (https://www.ucalgary.ca/mikebarry/TalkingTitler)	Talking Titler aims to secure land tenure in rural, underdeveloped regions. This is accomplished by recording verbal, media, and paper documentation into a database that is accessible to interested stakeholders. Talking Titler is a land tenure information software system that allows a great deal of flexibility in the way data relates people, land and evidentiary media. The software is intended to serve the following purposes: As a cadastral system or land record system prototyping tool where different data types and client needs can be simulated and piloted in the system and tested prior to a more rigid design being implemented; As a training tool for novice land record systems operators; or As a land tenure record system with the capacity to evolve from simple to complex models.
The Tropical Forest Community Mapping Initiative (TFCMI)/Mapping for Rights (http://mappingforrights.org/files/global-forestA4_FOR-EMAIL.pdf)	Mapping for Rights is a project that aims to secure land rights for indigenous and forest-dependent peoples through improved visibility. It accomplishes this through the use of technology to create an online community mapping platform whereby interested stakeholders can identify land area, land use, and land claims in areas where the project is being conducted.

Appendix E – Funders by Category

Technologies mentioning funders: 23

- Top Funders by number of technologies funded:
    - Omidyar Network (6)
    - USAID (4)
    - Bill and Melinda Gates Foundation (2)
    - East West Management Institute (2)
    - Open Society Foundation (2)
    - Ministry of Foreign Affairs of the Netherlands (2)
    - Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) (2)

Funders by Category

- Bilateral Government
    - USAID
    - Netherlands Ministry of Foreign Affairs
    - Deutsche Gesellshaft fur Internationale Zusammenarbeit (GIZ)
    - UK Aid
    - Swiss Agency for Development and Cooperation (SDC)
    - German Federal Ministry for Economic Cooperation and Development (BMZ)
    - Department for International Development (UK DFID)
    - Irish Aid
    - Government of Japan (Japan International Cooperation Agency)
    - Spider Center (Swedish Program for ICT in Developing Regions)
    - Swedish International Development Cooperation Agency (SIDA)
    - Norwegian Agency of Development Cooperation
    - Government of Finland
- Multilateral Government
    - EU (Horizon 2020)
    - Oxfam
    - European Commission
    - United National Human Rights Commission
    - FAO
- Philanthropic Organizations
    - BMGF
    - The Asia Foundation
    - Good Energies
    - Ford Foundation
    - Gordon and Betty Moore Foundation
- Private – For-Profit
    - Omidyar Network
    - Global Land Tool Network
    - Landgate
    - Adecco
    - HERi Africa
- Private – Not-for-Profit
    - International Land Coalition
    - East West Management Institute
    - Open Society Foundation
    - Climate and Land Use Alliance
    - Rights + Resources
    - American Jewish World Service

- Regnskokfondet (Rainforest Foundation Norway)
- Fundacion Tierra
- Rainforest Foundation Fund